INNOVATIVE COMPARATIVE ASSESSEMENT OF DIFFERENT REMOTE SENSING DATA FOR PROPERTY VALUATION FOR TAXATION IN RWANDA

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February, 2018

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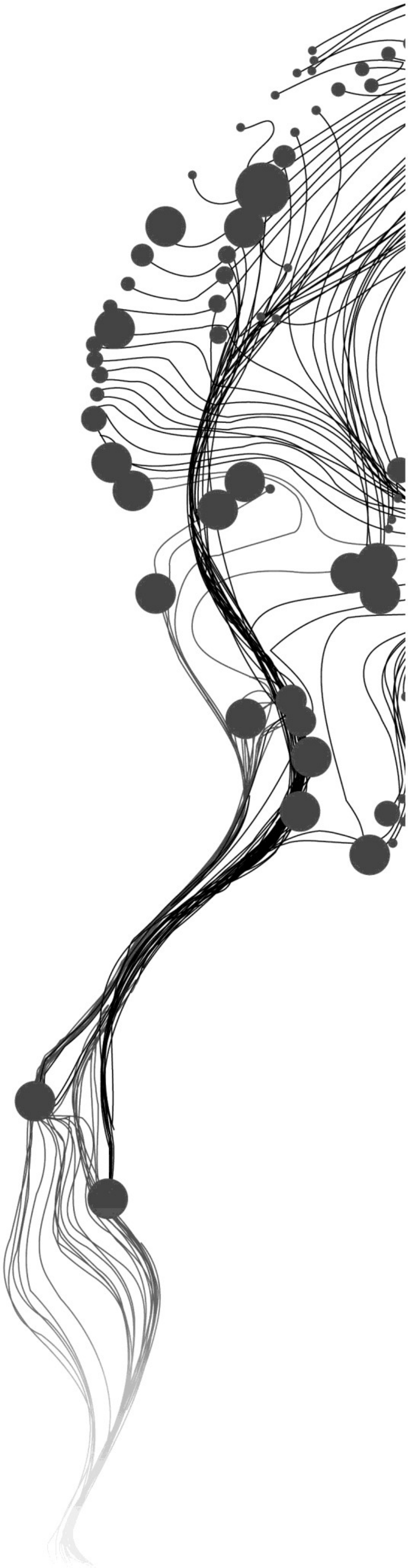

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OSCAR GASUKU
Enschede, The Netherlands, February, 2018

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

Property valuation requires updated and accurate information on the ground. Efficient techniques and tools needed for providing up-to-date information on the parcel in time and space. Recent advances in remote sensing data have proven to be useful for updating spatial information. However, the platforms differ regarding the spatial and temporal accuracy, costs and area of coverage. The current Rwandan cadastre, which is based on aerial photos acquired with a digital camera mounted on an aircraft in 2008, is not using images for property valuation for taxation. Recent studies have shown that unrecorded cadastral data can be captured or extracted from different remote sensing data such as satellite images, orthophotos from aerial images, and orthophotos from aerial UAV images as well as terrestrial images.

The study aimed to assess and compare different remote sensing data for property valuation for taxation in Rwanda. Results of comparison and assessment show that UAV dataset is most beneficial for property valuation for taxation purposes. The most important element in property valuation is accurate and up-to-date of information. Therefore, the data provided by UAVs was closer to the ground truth (measured with GNSS) compared to the orthophoto from aerial and satellite images. The developed UAV-based method for data collection for property valuation for taxation was done based on the findings from the comparison, interviewees and focus group discussion participants' views.

The developed method for data collection for property valuation for taxation in Rwanda is found to be useful for all the stakeholders. The foremost motivation behind adapting fit-for-purpose approach is to enable collecting required data at minimum cost, in the shortest time while upholding the required accuracy. Therefore, there is a need for further research on the efficiency of the developed UAV-based method for data collection for property valuation for taxation in Rwanda.

Keywords: *Property valuation, Property taxation, remote sensing data, land, property valuation method.*

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DEDICATION

This thesis is dedicated to the following people:

My beloved grandmother: Nyiranzabandora Adela
My beloved girlfriend: Louise Uwase
My brother: Bizimana Mugiraneza John
My Parental Uncles and their families

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LIST OF ABBREVIATION

CBD: Central Business District
DSM: Digital Surface Model
DSM: Digital Surface Model
EO: Exterior Orientation
GCP: Ground Control Point
GNSS: Global Navigation Satellite System
GoR: Government of Rwanda
GPS: Geographical Position System
HSRSI: High Spatial Resolution Satellite Imagery
ICAO: International Civil Aviation Organization
IO: Interior orientation
IRPV: Institute of Real Property Valuers
ITC: Faculty of Geo-information and Earth Science- former International Training Center
LAIS: Land Administration Information System
OSC: One Stop Center
RCAA: Rwanda Civil Aviation Authority
RCMRD: Regional Centre for Mapping of Resources for Development
RDB: Rwanda Development Board
RLMUA: Rwanda Land Management and Use Authority
RMSE: Root Mean Square Error
RRA: Rwanda Revenue Authority
RS: Remote sensing
UAVs: Unmanned Aerial Vehicles
UPI: Unique Parcel Identify
USGS: United States Geological Survey

1. INTRODUCTION

1.1. Background and Justification

The determination of the property value requires up-to-date information on entire property (including parcel, building and improvements). Advancements in geo-information and usage of remote sensing data are proven to be very useful to this end. Aggarwal (2004) defines remote sensing as a source of obtaining data about objects or areas at the Earth's surface without being in the field or direct contact with the object or area. Remote sensing data can, therefore, be used to update the information related to land parcels, buildings, land use, roads, and location. Dabrowski and Latos (2015) proved that different types of remote sensing data, due to their nature, have different potential regarding photo-interpretation, which directly links to the opportunity of their use as a basis of data about land and property. Due to differences in the spatial, radiometric, temporal and spectral resolution, they can be used for a variety of applications. It is an appreciated source of information about land, buildings and their changes in time.

Studies conducted about integrating remote sensing data for property valuation for taxation have shown that remote sensing data can be used to acquire and update cadastral information, which can support property valuation. For example, Dabrowski and Latos (2015), showed that during the initial phase of the property valuation of features, different remote sensing data can be used such as aerial orthophotos, satellite images, LIDAR data, multi and hyperspectral data. Dabrowski and Latos, (2015, p66) also highlighted that "*the most common type of remote sensing data used in the property valuation process are datasets available in the form of digital images obtained using different ranges of the electromagnetic spectrum from sensors placed on moving platforms flying at different heights*".

On the global scale, a study conducted by Haeusler, Gomez, Enßle (2017) and Ali and Deininger (2017) showed that remote sensing data especially High-Resolution Satellite Imagery (HRSI) data can be used to extract or measure the height of buildings. HRSI is useful for a variety of purposes such as urban planning, assessment of property taxes, as well as floor area and other additional attributes.

Furthermore, the property characteristics that can be obtained using remote sensing platform depend on the accuracy of the images acquired. There are different remote sensing platforms such as satellites, aeroplanes, helicopters and recently highly used Unmanned Aerial Vehicles (UAVs). Since its flying height is lower than the other platforms, UAVs can acquire images with very high spatial, temporal, spectral and radiometric resolution. Different researchers agreed that using UAVs can be very suitable for a variety of applications such as collecting and updating spatial data at an affordable cost (Koeva, Muneza, Gevaert, Gerke, and Nex, 2016; Muneza, Koeva, Gerke, Nex, and Gevaert, 2015).

Property valuation can be carried out for different purposes including sales, insurance, mortgage, taxation, financial report and others. The main characteristics of the property relevant to property value are location, accessibility, land use /zoning, laws and regulations, socio-economics, condition and age of the property, neighbourhood area's development" (Mihnea et al., 2017; Dabrowski and Latos, 2015; Maricor, 2015). Wallace and Williamson (2006) categorised property valuation in two approaches. The first is where the assessment of land and its improvement assessed for a single property and the second one is where valuation is for properties in a particular area. The later is also known as mass valuation. Accordingly, mass valuation is mostly carried out for taxation purposes. Property taxes defined as the duty of the landowner to local government. Property tax collection approaches differ from country to country.

Rwanda has a property tax, and land lease fee, both of which vary depending on the tax base. The property tax is determined based on the open market value. In Rwanda, the professional valuers prepare the valuation report of the property (parcel, buildings, and improvement on it). The tax amount is 0.1% of the total value of the property, while land lease fee is based on square meter rate determined by the district (GoR, 2012; GoR, 2011). The property tax relies on the percentage of the open market value of the property (Kauko, Heidi, Vicent, Juhopekka, and Hyyppa, 2016). Both single property and mass valuation intend to assess the open market value of the property (Wallace and Williamson, 2006).

This study aimed to assess and compare different Remote sensing data for property valuation for taxation in Rwanda. In Rwanda, there are studies conducted by various researchers on the use and applicability of Remote sensing data, e.g. Ayalew and Deininger (2017), researched on property tax in Kigali using the satellite imagery to assess collection potential.

1.2. Problem statement

The real property valuation profession in Rwanda is relatively new, with the law establishing and regulating the profession being adopted in 2010 (GoR, 2010). Before 2010, property valuation was carried out mostly by the civil engineers who had some training and experiences in property valuation methods (Thierry, 2014). Article 27 of Law no 17/2010 of12/05/2010, provides that "valuation of any types requires that the valuer apply one or more valuation approach described in this law or other method accepted by regulatory valuation council", the valuer should use the appropriate method that can be used to determine the open market value of the property.

Thus, the currently used valuation methods in Rwanda, as provided in article 28, of the real property valuation law are: "comparable price methods, comparison of land values national as another property valuation method, replacement cost approach as an alternative method for improvements and use of multiple valuation methods". All these methods are applied in Rwanda, whereby terrestrial data is collected using a digital camera to take pictures and tape measurement for registering the size of the property. Using a digital camera and tape measurement require direct contact with the objects of interest, and it is time-consuming, expensive and not very accurate.

However, the current Rwandan land cadastre built based on remote sensing data acquired with digital aerial camera in 2008 is missing essential information. For example, Rwandan land cadastre is missing buildings, built-up area, an improvement on land, accessibility, zoning, floors of structure and its condition and age of construction and also there hasn't been a regular updating of the orthophoto or the map after 2008 (Uwihoreye, 2016). Integrating these factors during property valuation process is often challenging due to inaccessibility of data (Freeman, 2017). Unrecorded cadastre data can be captured or extracted using different Remote sensing data such as satellite images, orthophotos from aerial images, orthophoto from aerial UAV images and terrestrial images (Dabrowski & Latos (2015). It can be beneficial for property valuation for taxation purposes.

Thus, this research aims to assess and compare the usability of remote sensing data as methods of data collection for property valuation for taxation purposes. The developed criteria for comparison was done and tested in Rwanda using different remote sensing data. Therefore, the developed approach using remote sensing data compared with the currently used methods for data collection for property valuation is done. The evaluation of the developed method for data collection for property valuation for taxation purposes in Rwanda was carried out during the fieldwork.

1.3. Research objectives and research questions

1.3.1. General objective

The main objective of this study is to assess and compare the usability of different Remote sensing data for property valuation for taxation purposes in Rwanda.

1.3.2. Specific objectives and research questions

Sub-objectives and research questions for each sub-objective were developed and are the following:

1. *To review the current property valuation for taxation system in Rwanda*
    1.1 What are the laws, regulations, policies, challenges, and institutions/stakeholders currently involved in property valuation for taxation system in the in Rwanda?
    1.2 What are the policies, regulations, limitations, and challenges regarding usage of Remote sensing data for property valuation for taxation in Rwanda?

2. *To develop a new approach for data collection for property valuation for taxation in Rwanda using Remote sensing data.*
    2.1 What are the procedures or steps for remote sensing data acquisition for property valuation and taxation?
    2.2 What are the Remote sensing data requirements for property valuation for taxation purposes?

3. *To evaluate the new developed approach against the developed criteria's for property valuation for taxation purposes in Rwanda*
    3.1 What are the evaluation criteria's for a new developed method using Remote sensing data compared to the current property valuation for taxation approach?
    3.2 What are the results of the evaluation of a new developed method based on the Remote sensing data?
    3.3 What are its advantages and disadvantages?

1.4. Conceptual framework

Criteria for evaluation based on the factors that affect the value of the land as described by Wyatt (1996) as shown in Figure 1. Different researchers have adapted these factors, for example, Demetriou (2016) adapted the criteria for the valuation of land consolidation. The current property valuation methods in Rwanda are described by the law N^0 17/2010 establishing real property valuation profession in Rwanda (GoR,2010). While property taxation methods are described in the law N^0 59/2011 establishing the sources of revenue and property of decentralised entities and governing their management (GoR, 2011). The usability of remote sensing data for valuation based on the adapted criteria was defined. The effect and implications of these factors or criteria's on the value of the property and its implication on the methods for valuation were assessed.

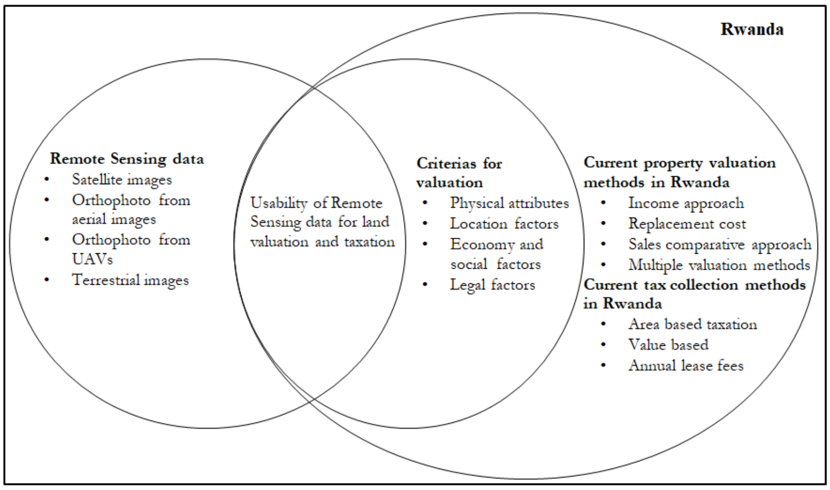

Figure 1-1: Research conceptual framework

Table 1-1, shows how the key concepts are operationalised from the conceptual framework in this research. The table indicates the specific objectives, concept, and dimension of the concepts, research questions, indicators and variables that show how the dimension and indicators were measured.

Table 1-1: Operationalisation of the concepts

Research sub-objectives	Concept	Dimension	Research questions	Indicators	Variables/ how to measure
To review the current property valuation for taxation system in Rwanda	Property valuation and taxation	Laws Regulations Policies Standards Reports	What are the laws, regulations, policies, challenges, and institutions/stakeholders currently involved in Property valuation for taxation valuation system in Rwanda? What are the policies, regulations, limitations, and challenges regarding usage of Remote sensing data for property valuation for taxation in Rwanda?	- Tax rate - Valuation methods - Steps involved in property valuation - Type of land tenure - Methods of property tax - Types of land taxes	- Rate per sq. meter - % of property value - Number of taxpayers - Number amount to be collected - Taxpayers workflow
To develop a new approach for data collection for Property valuation for taxation in Rwanda using Remote sensing data.	Remote sensing data	UAVs Satellite Aerial orthophoto Terrestrial images	What are the procedures or steps for remote sensing data acquisition for property valuation and taxation? What are the remote sensing data requirements for property valuation and taxation?	- Procedures - Accuracy - Time(up-to-datedness - Completeness - Cost - Availability of platform	- Number of steps - Spatial resolution - Temporal resolution - Affordability

To evaluate the new developed approach against the developed criteria's for Property valuation for taxation in Rwanda	Developed criteria	Physical attributes Location factors Legal factor Economic and social factor	What are the evaluation criteria's for a new developed method using remote sensing data compared to the current property valuation for taxation approach	- Parcel size - Tenure type - Built-up area - Accessibility - Zoning - Land use	- Square meters - Height - Roads networks - Residential commercial, industrial and Agricultural.
			What are the results of the evaluation of a new developed method based on the Remote sensing data?		
			What are its advantages and disadvantages?		

1.5. Scope

This study focused on assessing the applicability of four different types of remote sensing data:

(1) Satellites images_Worldview 2 acquired in 2013,
(2) Orthophoto from digital aerial images acquired in 2008,
(3) Orthophoto from aerial UAVs images acquired in 2015,
(4) Terrestrial images from 2017 for property valuation for taxation purposes.

The comparison of regarding the spatial data accuracy, cost and time. Additionally, the data was also compared based on physical factors like parcel area, built-up area, land use, accessibility and neighbourhood development. The study focused on land or property valuation for taxation purposes.

1.6. Structure of the thesis

The structure of this thesis is composed of seven chapters with sub-titles. The first four chapters were written in the pre-fieldwork period and updated after fieldwork. The last three chapters are about the collected data from the fieldwork, discussion and conclusion and recommendation.

Chapter 1: Introduction

This chapter provides an understanding of the background and justification of the research. The research problem and objectives to address the research problem are discussed in this chapter. The key concepts and its conceptualisation and scope of this work are defined.

Chapter 2: Literature Review

This chapter aims at reviewing different literature such as journals, book, and academic papers about this research. The relevant literature about Remote sensing data, property valuation for taxation, and factors affect the property value are discussed in this chapter.

Chapter 3: Research Methodology

In this chapter, the methods used for data collection and analysis were discussed. The research design was developed and followed. The used dataset and study area for this research is described in this chapter.

Chapter 4: Results

The results of collected data both primary and secondary are presented according to the objectives.

Chapter 5: Discussion of the results

The results from chapter 4 is discussed in this chapter and are presented according to the objectives and findings

Chapter 6: Conclusion and recommendation

The overall conclusion and recommendation of this research are addressed in this chapter.

2. LITERATURE REVIEW

In this chapter, a broad review of the concepts of usability of remote sensing data in property valuation is reviewed. Different remote sensing data from four platforms such as Unmanned Aerial Vehicles (UAVs), aircrafts satellites and terrestrial; and their applicability are reviewed and discussed. Property valuation methods and factors affecting property value were reviewed and adapted in the context of Rwanda. Furthermore, a fit-for-purpose approach for data collection using remote sensing data is discussed in this chapter.

2.1. Remote sensing

Remote sensing has been defined as the art and science of getting data about the earth surface without having any physical interaction with it (Jensen, 2005; Admin, 2016; Natural Resources Canada, n.d.). This is done by detecting and recording of reflected and emitted energy. The process of remote sensing involves an interaction between the incoming radiation and interest of target (Abdulrahman, 2010). The processes are done either by using imaging or non-imaging system (Know Basics of remote sensing Quickly and Become Expert, 2015). In the present research, the focus is on image-based acquisition techniques.

2.1.1. Satellite Images

A satellite can be defined as a body that can be positioned in trajectory around the Earth or another planet with a mandate of data collection of data or communication (Natural Resources Canada, n.d.). According to NASA, a satellite is a body of orbits around another body in space. Satellites are categorised into two different types such as natural satellites and human-made satellites. Natural satellites include Earth and Moon while human-made satellites are those fabricated by a human being and launched into space and orbits around a body in space. The latter comes in many shapes, sizes, and forms where different instruments are attached to it to perform various functions while being in space (Thuy, 2017).

Lots of studies on the applications of satellite imageries have been done, for example in land use monitoring, mapping and master plan preparation, cadastre serving (Malarvizhi, Kumar, and Porchelvan, (2016; Alexandrov et al., 2004). According to Jacobsen (1986), high spatial resolution satellite imagery (HSRSI) is a suitable source of information for creation of preliminary index diagrams with the case study of Kenya. The results show that HSRSI is very applicable for surveying large areas in time and are cost effective and can be considered as useful input for land surveying methodology. Another example is a study conducted by Ayalew and Deininger (2017) in Rwanda, where the objective was to explore the potential of combining land administration and remote sensing data for mass valuation of properties in Kigali city. The study showed that HRSI can be used to improve the property or land taxation collection by increasing the revenues.

2.1.2. Orthophotos from aerial images

Aerial imagery can be obtained using conventional platforms such as aircraft or helicopters. Nonetheless, their temporal resolution is limited by the obtainability of aircraft platforms, pilot licenses, flight regulations, the expertise of the specialists (Turner, Lucieer, and Watson, 2012). Due to this limitation in developing countries, it is hard to be used for the regular update of digital information.

In 2008 and 2009, a traditional aerial survey was executed over the territory of Rwanda through a digital photogrammetric camera; post-processing procedures were completed by a Dutch photogrammetric company (Muneza, 2015). After processing, the outcome for the entire country such as elevation information was generated, and an accurate orthophoto was produced. Based on these sources, a digital base map covering the whole country was created. The produced orthophoto was characterised by spatial resolution (Ground Sampling Distance) of 22cm. The raw images were acquired from a 3000m flying height, using a digital camera, the Vexcel UltraCamX (Muneza, 2015). According to the research conducted by Fosudo (2014) on land tenure regularisation in Rwanda, the outcome of agricultural land use change in peri-urban in Kigali showed that the radiometric and spectral resolution of the orthophoto acquired in 2008 is respectively 3bands and 8-bit pixel. This was a huge step for using of remote sensing data in Rwanda which provided useful, accurate digital data and generated orthophoto for the whole country.

2.1.3. Orthophoto from Unmanned Aerial Vehicle (UAV) images

According to the Unmanned Vehicles System (UVS), the global definition of Unmanned Aerial Vehicles (UAVs) is a broad aircraft design to function deprived of human pilot onboard. The used terminology depends on their force system, altitude and level of automation are: Unmanned Aerial System (UAS), Remotely-Piloted Aerial Systems (RPAS), Unmanned Aerial Vehicles (UAVs), Drones, Remotely Operated Aircraft (ROA), Micro Aerial Vehicles (MAV), Unmanned Combat Air Vehicle (UCAV) (Remondino, Barazzetti, Nex, Scaioni, and Sarazzi, 2011).

The background of UAVs shows that it was firstly used by the military to achieve their goals and applications: inspection, surveillance, reconnaissance and mapping of inimical areas that were the primary military objectives (Nex and Remondino, 2014; Remondino et al., 2011; Colomina and Molina, 2014). Nowadays, UAVs are progressively being used in civil and scientific research due to their potential and attractiveness for acquiring remote sensing data more quickly at lower cost and flexibility compared to the piloted aerial vehicles (Everaerts, 2008; Muneza, 2015; Koeva, Muneza, Gevaert, Gerke, and Nex, 2016). Recently, use of the UAVs for gathering of spatial information improved due to their technological development regarding manoeuvrability, costs, and flexibility in geodata acquisition (Freeman, 2017).

Research on the applications of UAVs data has been conducted recently such as cadastral mapping, agriculture, disaster management, environment, archaeological, cultural heritage, and informal settlement control.

Cadastral mapping: A study carried out by Ramadhani (2016) on using UAS to support cadastral boundary data acquisition in Indonesia, showed that this approach can be seen as a worthy alternative for data acquisition. Muneza (2015) generated a high-accurate orthophoto and proved that it could be used for accurate mapping both in urban and rural areas. The benefits of using UAVs data for cadastral mapping was shown in Albania (Barnes, Volkmann, Sherko, & Kelm, 2014) and Namibia for customary right registration (Mumbone, Bennett, Gerke, and Volkmann, 2015). The study conducted by Muneza et al. (2015) on photogrammetric approach for map updating using UAVs in Rwanda showed that the UAVs can be used to update the outdated existing orthophoto base maps of acquired in 2008. Koeva et al. (2016) in the research entitled on "using UAVs for map creation and updating" also use Rwanda as the case study. The results of this study proved that UAVs can offer promising opportunities to produce high spatial and temporal resolution low-cost data.

Informal settlement: The research conducted by Gevaert, Sliuzas, Persello, and Vosselman (2015) in Rwanda, on opportunities for UAVs mapping to support unplanned settlement upgrading. The study indicates that the establishment of highly-accurate and up-to-date information from UAVs permits the recording of the existing situation to the extended area. These include structures, transportations infrastructures, land use, drainage, and other points of importance which are dynamic for upgrading developments. Gevaert, Persello, Sliuzas, & Vosselman (2017) also show that UAVs can provide very high-resolution and current information to support informal settlement upgrading projects. They further demonstrate UAVs potential for classifying informal settlements.

Agriculture: UAVs were proved to be a valuable source of information also for farming yield by obtaining more real data about land and production features. Such data can be used for irrigation process by determining the needs, crop surveying, disease monitoring and also fertilisers (Muneza, 2015; Remondino et al., 2011; Grenzdörffer, Engel, and Teichert, 2008; Ahir and Patel 2014).

Disaster and risk management: UAVs can also be used for disaster and risk management such as fire and safety management, emergency response, flood, and earthquake response without exposing the pilot to risks. For example, Fernandez Galarreta, Kerle, and Gerke (2015) researched on UAV-based urban physical destruction assessment using object-based image investigation and semantic reasoning.

2.2. Property valuation

Valuation has been defined as an estimation of the worth of a subject property interest at the date of valuation, given in writing (RICS, 2008). Unless limitations are agreed regarding engagement, this is provided after an inspection and any further investigations and inquiries that are appropriate, having regard to the nature of the property and the purpose of the valuation. Property valuation can be defined as procedures for arriving an opinion of value exchange under the particular assumption (Petter Wyatt, 2013).

2.2.1. Property valuation approaches

Property valuation methods are considered as the tools that the valuers used to assess the value of the property by taking into consideration the factors that can affect the property value. Therefore different approaches have been developed and used by various institutions and profession valuers. These methods are used independently depending on the available data. Combinations of data sources and used methods are also possible.

According to Pagourtzi, Assimakopoulos, Hatzichristos, and French; (2003) grouping property valuation methods into two clusters, traditional and advanced methods, are appreciated. Traditional valuation methods are comparison method, investment method, profits method, development method / residual method, contractor's method/replacement cost method, automated valuation models, and computer-assisted mass appraisal, multiple regression methods, and stepwise regression method. Advanced methods include artificial neural networks (ANNs), Hedonic pricing method, spatial analysis methods and others (Pagourtzi et al., 2003).

According to the law N°17/2010 establishing and organising the real property valuation professional in Rwanda, the current valuation methods applied in Rwanda (GoR, 2010), as described in section 1.2 are discussed as follows:

- **Comparable sales approach**: Here, the proposed values of the property are close or equal to the open market value. The valuer compares prices recently sold by referring to the prices recently assigned property that is alike or comparable to the real property subject to valuation.
- **Comparison of land values countrywide as an alternative property valuation method**: Where comparable prices are not accessible for land in a particular area, the valuer may use comparable prices of similarly classified land from other areas of the country. Prices shall vary depending on the quality and location of the land. The valuers shall fulfil their valuation duties in compliance with principles and regulations governing the valuation profession and the Council.

- **Replacement cost approach as an alternative valuation method for improvements**: Where sufficient comparable prices are not existing to determine the value of improved land, the replacement cost approach shall be used to determine the value of buildings and improvements to land by taking real property as a reference.

- **Use of multiple valuation methods**: This approach is used where the property valuation requires special skills; the valuers shall use whatever combination of the methods they consider best suited to determine the current market value. The methods used shall be explained in the valuation report. The law also specified that "*upon approval by the Council, a valuer may use any other relevant worldwide methods not provided in the valuation law to carry out the assigned work*".

2.2.2. Usability of remote sensing data into property valuation profession in Rwanda

In Rwanda, remote sensing data has been used in land matters since 2008. Through traditional aerial photography performed over the territory of Rwanda with a digital photogrammetric camera (Muneza, 2015). The generated orthophoto was useful during systematic land registration using fit-for-purpose approach. Rwandan land cadastre was built based on the orthophoto from aerial images and satellites images (Enemark, Bell, Lemmen, & McLaren, 2014). Local citizens employed and mainly trained 'para-surveyors' delineated the parcel limits on the imagery printouts that were scanned, geo-referenced and digitised (Enemark et al., 2014). Currently, property valuation is relying on the data provided by Rwanda land use management authority (RLMUA) especially parcel area, the location of the property and also the land use; all this information can be obtained from the land title and also field visit. For instance, Rwanda National land use masterplan was developed based on the generated orthophoto from aerial images, therefore, developed a master plan for Kigali city is being used as a source of property valuation data (Sagashya, 2014).

2.2.3. Spatial Criteria for property valuation/ factors affect the property value

Regarding property valuation, the word 'value' is commonly introduced by explanations such as reasonable value, market value (Yomralioglu and Nisanci, 2004). Open Market value, since it refers to "*the estimated amount for which an asset or responsibility should exchange on the appraisal date between a willing purchaser and a willing vendor in an arm's length transaction*. When proper marketing and where the parties had each represented expertly, prudently and without compulsion, this approach for taxation is used where the country has a developed land and property markets, and this operates formal property markets" (IVSC, 2016). The importance of valuation is interpreted as a complex process which involves reflection of some underlying market, economic, physical, political and social elements and how their impact on the value of a property at any time (Walacik, Grover, and Adamuscin, 2013).

Wyatt (1996) groups the factors influencing land or property value into two groups, internal factors, and external factors. Yomralioglu and Nisanci (2004) argued on these factors and emphasised on how they can influence the value of certain property. Figure 2-1 below shows the factors that influence property value and are adapted from Wyatt (1996). This research focused mainly on geospatial factors such as the physical attributes (e.g., parcel area, built-up area/gross floor area), locational factors (e.g., accessibility, neighbourhood development, and environment).

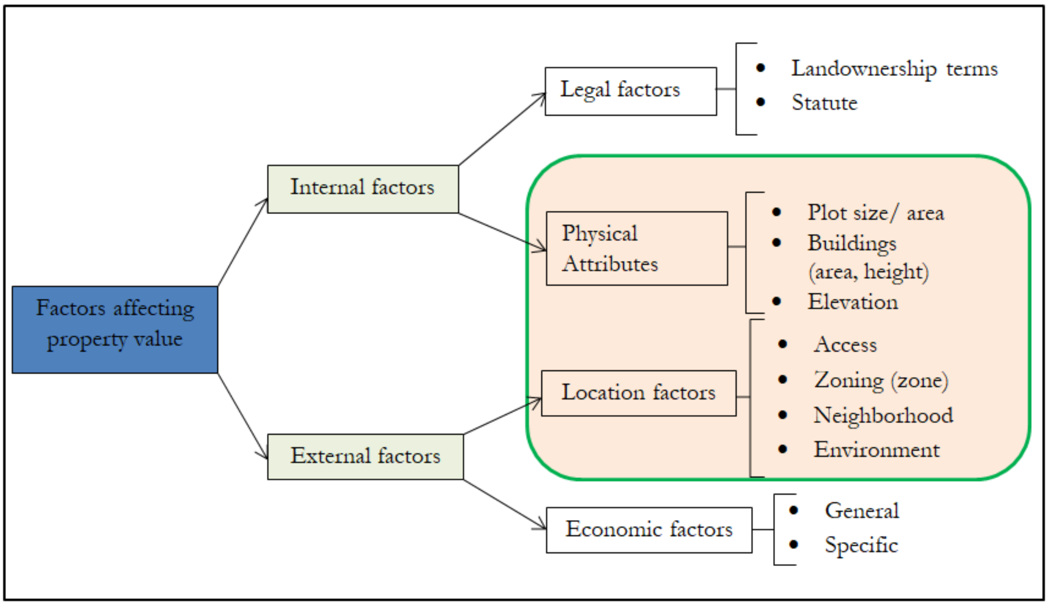

Figure 2-1: Factors affecting property value

The table below shows the features that can be extracted from different remote sensing data as adopted from Dabrowski and Latos (2015).

Table 2-1: Possible features that can be extracted from remote sensing data (Source: Dabrowski, 2015)

Datatype	**Building**								**Land**				
	Area	Localization	Neighborhood	N0. of floors	Fittings	Tech. condition	Area	Localization	Neighborhood	Shape	Type	Development	Utilities
Orthophoto	+	+	+	+/-	-	+	+	+	+	+	+/-	+	+
Raw satellite and Aerial images	-	+	+	+/-	-	+/-	-	+	+	+	+/-	+	+
Raw images from an UAV	-	+	+	+	+/-	+	-	+	+	+	+	+	+

In this Table 2-1 above, the "+" symbol indicates those features that can be extracted from different types of remote sensing data. The "+ / -" means that the feature is likely to be determined under certain conditions. The symbol "-" means that there is no possibility of identifying the given feature.

2.3. Property taxation

Taxation is one of the duties of the landowner to the government. Property tax also can be viewed as the sources of revenue for local governments. The reason why land and property have to be considered to be particularly appropriate as a local source of income is that real property is immovable, it is not capable of moving its position in response to duty. Another reason for the connection between many of the services typically funded and implemented at local level and benefit to property values (Bird and Slack, 2002).

Bases of property taxation

Property tax collection approaches differ from country to country. Property or land taxes drives on different sources of value of which the two broad bases are area-based and value-based (Mangioni and Kauko, 2014).

Typically, area-based taxations are used for determining the assessed value of the property where the property markets are not well developed to support value-based system (Mccluskey & Plimmer, 2007).

Area-based taxation versus Value-based

For the area-based tax, the taxes build on the unit, and therefore the unit assessment must be regarding the rate. The rate is levied per m² of the land area, buildings or combination of the two. The unit's price estimate reflects the location or others factors, such the location of the property, accessibility, land use /zoning, laws and regulations, socio-economics, condition and age of the property, neighbourhood area's development. This method of tax collection is utilised by the countries where there is an absence or weak real estate market (William & Franzsen, 2016). Value-based taxation is based on the market value, annual (rental) value and land site or site value.

In Rwandan, the property tax is governed by the Law N° 59/2011 of 31/12/2011 establishing the basis of income and property of decentralised entities and leading their management (refer to as taxation law). The article 5 of the same law, states, and categorises the tax which could be collected by the local government as "fixed *asset tax, trading licensed tax, and rental income tax".* The article 2 of the same law defines the fixed asset tax as a tax levied on immovable property. The right-holder pays this tax under freehold title; and the fixed asset has been defined as property that has a fixed location and can't be moved elsewhere and includes parcels of land, buildings, and improvement on it (GoR, 2011).

Article 6 of the Law No 59/2011 of 31/12/2011 also provides that the fixed asset tax is levied on the open market value of land, buildings and all improvements registered with the Land Registration Center. For which the landowner has obtained a title deed from the time the building is inhabited or used for other activities; the value of land exploited for quarry purposes; the market value of a usufruct with a title deed. Article 17 of the taxation law, also stipulates that when the fixed asset tax constitute a bare land (parcel of land not developed), the market value shall constitutes per square meter value times the size of the parcel. While where the fixed asset involves a parcel of land, building, and improvements, the collective value of them, constitute the market value of such fixed asset. Where a parcel, buildings, improvement, and usufruct have been pay for, the purchase price shall be taken as the tax base, except if it is clear that the purchase price is below the market value (GoR, 2011). The rate of fixed asset is fixed at 0.1% of the total value of the taxable asset per year; the same rate is applicable for the land being used as a quarry.

The two forms of tenure in Rwanda are full ownership (freehold title) and long leasehold title. As mentioned early in the introduction that about 98% of Rwandan land is held under leasehold, which means that only 2% of the Rwanda territory is thought under freehold. Only 2% of Rwandan land is supposed to pay tax as a fixed asset. The implementation of Law No 59/2011 of 31/12/2011, the government enacts presidential Decree No 25/01 of 09/07/2012 instituting the list of dues and other responsibilities levied by decentralised entities and determining their thresholds. Regarding the above order, those lands owned in the long lease have to pay the annual lease fees. The annual rental fees are not based on the market value of the parcel; they are based on a rate per square meter determined by the district council, which also varies according to the development within area or location and land use. The presidential order specifies the maximum and minimum rate required in in each category, and also it lists all kind of land and property are exempted from paying both tax and annual lease fees.

Rwanda taxation system applies both areas based and value-based tax approach. Furthermore, the two methods of taxation are based on the market values which require determination of the open market value of the fixed asset. The opinion's value of the property is determined by the competent valuer, registered by Institute of Real Property Valuers (IRPV). Although there are challenges to the taxpayer regarding these methods, such as payment fees charged by the valuer as extra expenses. This challenge also is faced by the tax collector where if they want to conduct the revaluation of the taxable property the value of revaluation is greater than taxes value (0.1% of the total value). The result of this challenges leads to underestimation of the value when the valuation purpose is for taxation.

2.4. Comparison of the different remote sensing data

This section aimed at comparison and description of the used remote sensing data. The comparison is based on the characteristics of the generated orthophoto from the used dataset. It will be described in chapter 3 section 8.

2.4.1. Satellite images

Thousands of satellites exist, European and non-European (Acker, Pötscher, & Lefort, 2012). In this research satellite, Worldview2 is used. There are two possibilities to use satellite images. The two options are either to order an acquisition according to the concrete requirements or to purchase the existing images from archives. According to AAAS (2017) and LandInfo (2016) categories, the prices of satellite images depend on the available data. When ordering the new high-resolution satellite images, the price is not the same as ordering the existing images in archives. The used Worldview2 orthophoto in this research is characterised by the spatial resolution of 0.5 m, and its temporal resolution of 1.1 days, with a radiometric resolution of 16_bit and 4 bands for spectral resolution.

- ***Ordering new high-resolution images***

Ordering is a process of request something to be made, supplied, or served. The request or the order is determined by the factors and the specifications the user need from the seller. For instance, ordering the new high-resolution images from satellite-Worldview2 require different factors such as well determined and described the location, characteristics of images, the purpose of the images, required resolution and cloud cover. The price of ordering the new high-resolution images for Worldview2 range from $24.00 to $29.00 per km^2 (LandInfo, 2016). The smallest area that can be ordered is 100 km2 with a 5km minimum ordered width.

- ***Purchasing existing images- ordering archives images***

Ordering archive satellite-Worldview2 images require different factors as described above; the difference is that the image characteristics, capture area and quality might not meet the buyer's requirements due to the acquired images was for other purposes. For archives, the price of satellite-Worldview2 images varies from $14.00 to $19.00 per km2. The minimum area that can be ordered is 25 km2, with a minimum width of 2 km, the requested data is older than three months in archives.

2.4.2. Orthophoto from aerial images from both aircraft and UAVs

Aerial imagery can be acquired using conventional platforms such as satellites and aircraft; however, their temporal resolution is limited by the availability of the orbit characteristics of satellites and aircrafts platform (Turner, Arko, & Watson, 2012). The Orthophoto from aerial images can be obtained using aircraft or another platform with a digital photogrammetric camera mounted on it. The acquisition should be done by the eligible company to fly according to the regulatory framework. Therefore, all post-processing procedures should be done by experienced professionals working in a photogrammetric company. If the above mentioned is applicable from the local company then is considered as own acquisition. However, in Rwanda, this approach is quite innovative, and there are still not existing companies to do with high quality the full process of data acquisition, therefore, hiring external company may be more suitable. The requirements for images to be acquired should be well defined, e.g. size area, resolutions, well-described location, imaging purposes etc. The cost of hire and order is different because hiring involves much-incurring cost such as platform, pilot, fuel, post-processing cost and staff; while ordering requires ordering the existing data and does not involve much time because the data is available.

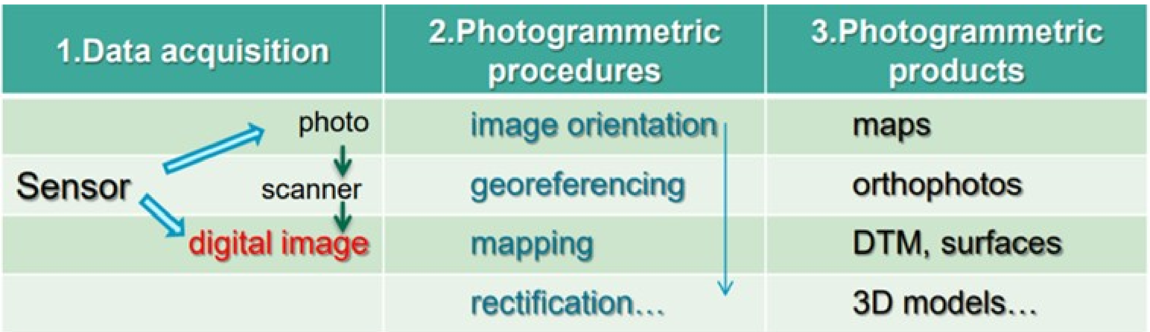

Figure 2-2: Aerial photogrammetry process (Source: Lecture slides Module6 LA)

- ***Orthophoto_2008 from aerial images taken by Aircraft***

The used orthophoto from aerial images in this research was acquired in 2008 using aircraft. The existing land cadastre spatial data in Rwanda based on it as the orthophoto was used during systematic land registration. The orthophoto description as shown in Table 3-4 is characterised by the spatial resolution of 25cm, with 8-bit of radiometric resolution and 3 bands of spectrum resolution. All post-processing processes were done by the foreign company (Dutch Photogrammetry Company). The generated digital surface model and orthophoto were used to digitise a detailed base map of existing spatial dataset and field sheet preparation. The developed Rwanda national land use master plan and topographic maps were based on generated orthophoto (Muneza, 2015).

- ***Orthophoto from UAVs images***

The Orthophoto from UAVs images can be obtained using unpiloted aircraft usually called "Drones" in Rwanda with a digital photogrammetric camera mounted on it. The acquisition should be done by the eligible company to fly UAVs according to the regulatory framework. The used orthophoto generated from UAVs as described in Table 3-4 is characterised by the spatial accuracy of 3.3cm, with 8-bit of radiometric resolution and 4 bands of spectrum resolution (Koeva et al., 2016).

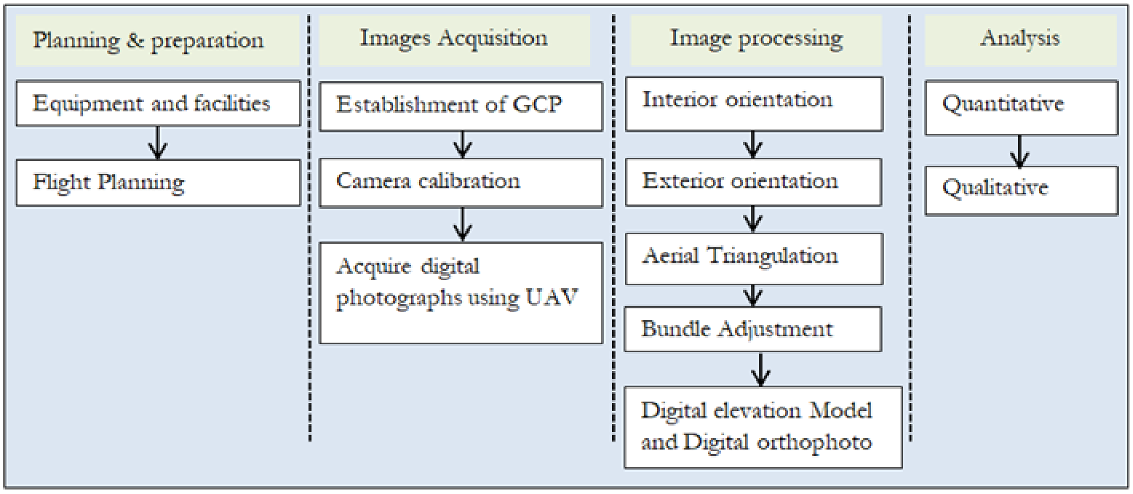

Figure 2-3: Adapted photogrammetric process (Udin & Ahmad, 2014)

Technically, UAVs can fly almost everywhere, their flexibility is high, and this fact allows them quickly to change the observed location and viewing angle in short time (Koeva et al., 2016).

3. RESEARCH METHODOLOGY

This chapter describes the research procedure used to reach the objectives of this study. It further describes the methods used to collect both primary and secondary data.

3.1. Research Methods

Qualitative and quantitative methods were used in a mixed methods approach. The guide questions for interview and focus group discussion were open-ended questions. Bryman (2012) described the quantitative as an approach to numerical data collection; show the link between theory and research as logical and a predilection for a natural science approach. The quantitative approach was used to collect the secondary data related to land tenure type as classified. The total numbers of parcels with land lease certificate compared to those with freehold titles were collected from RLMUA LAIS database as updated up to October 2017.

The qualitative method was used to understand how the current property valuation and taxation system works in Rwanda. The qualitative method was used to answer questions such as who are key players involved in valuation and taxation? What are their roles? Is there a valuation standard? If no, which law is regulating property valuation? What are the limitations and challenges of collecting data using RS data? These were open-ended questions, where the respondents expressed their idea and what they thought about the subject-matter. The qualitative methods in this research were also used to understand the perceptions of the stakeholders especially governments institutions on using the remote sensing data for property valuation for taxation purpose.

3.2. Research design

The research was distributed into three main phases namely, (1) Pre-Fieldwork, (2) Fieldwork and (3) Post-Fieldwork as described in Figure 3-1.

3.2.1. Pre-fieldwork

Throughout pre-fieldwork stages, the fundamental concepts of property valuation for taxation and remote sensing were reviewed converging on using remote sensing data as a fit-for-purpose approach to support the property valuation for taxation. Based on the reviewed literature, the background and justification of the research were developed, and research problem defined. The research objectives and research questions were formulated to address the research problem. The review of the documents was done to answer part of the specific objective 1 and 2. As specific objective one intended to review the current property valuation for taxation purposes (fixed asset tax) system in Rwanda, a review of laws, regulations, order and reports related to property valuation, property tax (fixed asset tax) and using remote sensing techniques in Rwanda was done. Results or summary of the reviewed documents and finding are presented in chapter 4 section one.

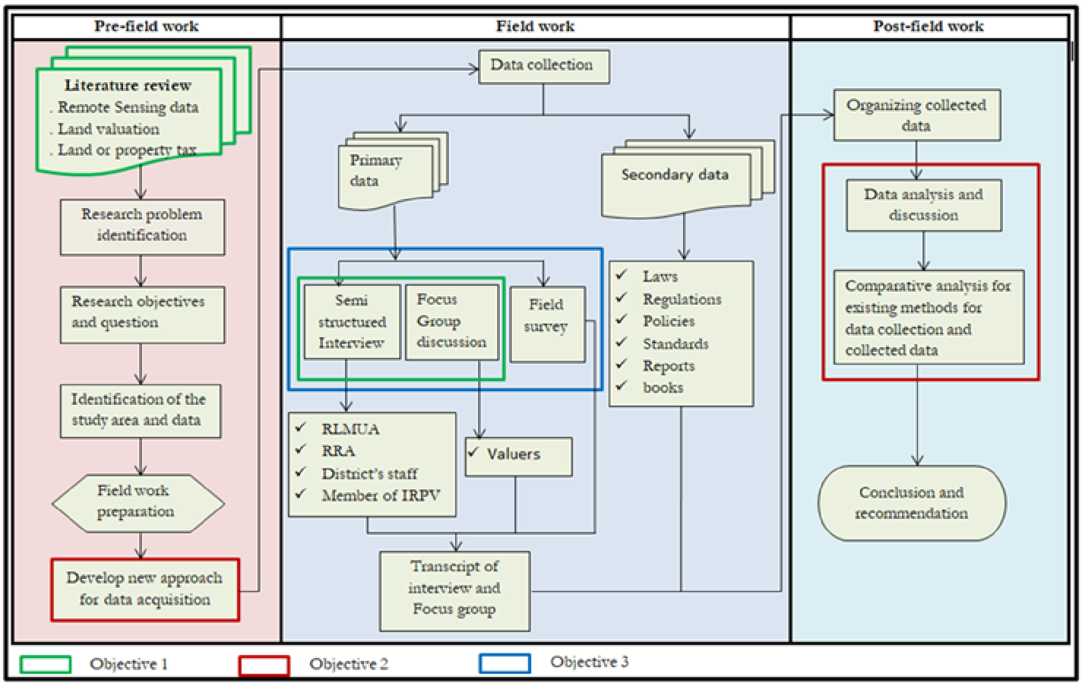

Figure 3-1: Research design workflow

3.2.2. Fieldwork

The fieldwork stage involved the collection of primary and secondary data. Semi-structured interviews and focus group discussion were used to collect primary data. The Table 3-1 shows the distribution of interview respondents according to their institutions. One focus group discussion with eight valuers was conducted during fieldwork. After the interviews and focus group were conducted, a field visit followed, in which geodetic surveying and observation by taking field measurement and acquisition of terrestrial images. The field measurement was done on the basis of comparison from LAIS-database, measured and data from remote sensing. Section 3.3 details how data were collected and findings are presented in chapter 4.

3.2.3. Post-fieldwork

Post-fieldwork period involved data presentation and analysis. In this stage, the collected data was analysed using different methods of analysis and software as described in section 3.6. Regarding the analysis of data, discussion of findings was done followed by a conclusion, and recommendations, as well as further research of this study, were proposed.

3.3. Data collection methods

This section discusses the methods used to collect the required data intended for this research. The primary data was gathered using semi-structured interviews, focus group discussions and field survey measurement and terrestrial images acquisition while for the secondary data, the desk study or literature was used to review and compile the related literature.

3.3.1. Semi-structured Interviews

A semi-structured interview involves a researcher gathering detailed information from an interviewee by asking direct questions but giving room for the interviewee to explore their area of interest and disclose relevant issues (Silverman, 2005). The interview technique is used to gather information and includes the presentation of oral-verbal stimuli and reply in terms of oral-verbal replies (Kothari, 2004). This method can be used either for face to face personal interviews or telephone interviews. In this, this research "*Face to face personal interview*" was used, and the respondents from different institutions were determined based on their organization and functions. The interview was conducted to address the gathered data on current land and taxation system and limitations of using remote sensing data in property valuation for taxation purpose. The respondents were from different government institutions from both local and central level. At central level the officials from RLMUA, RRA and IRPV were interviewed whereas at local level district officials were interviewed. The interview guide questions were mainly related to the current real property valuation practice focusing on the purposes of taxation and usability of remote sensing in land or property valuation for taxation purpose.

Figure 3-2: Interview discussion with director of finance Gasabo district

The expected respondents as described in Table 3-1 below, during pre-fieldwork teen respondents from semi-structured interviews were planned. However, thirteen respondents were interviewed, one official from Ministry of Infrastructure as key Ministry has transportation and aviation in their responsibility was added. Also, former Director General of Rwanda Natural Resources Authority, currently working as Director General of Regional Centre for Mapping of Resources for Development (RCMRD) and IRPV the number of respondents increased and reached up three respondents.

Table 3-1: Number of respondents by institutions

Institutions	Category of respondents	Distribution of respondent		
		Planned	**Achieved**	**Achieved percentage**
RLMUA	Central government	3	2	66.7
RRA		2	3	150
IRPV		2	3	150
Ministry of Infrastructure		0	1	100
DISTRICT	Local government	3	3	100
RCMRD	Regional	0	1	100
Total		**10**	**13**	**130**

3.3.2. Focus group discussions

Further data was collected using the focus group discussion, involving between six to twelve persons who share similar characteristics or interests (ATCC, 1996). During the focus group discussion, the facilitator to the researcher guided the participants in the group based on the discussion topic. The collected data from Focus group discussions were qualitative data. The focus group participants were selected based on their professional backgrounds, and the targeted group was valuers. It was conducted as the basis for understanding the current valuation of taxation practices in Rwanda and the evaluation of the developed methods for data collection for property valuation for taxation purpose.

Before, the focus group discussion started, the researcher introduced to the participants the overview of the research. The consent form was distributed to the participants, and eight people agreed to participate and to sign it. The focus group discussion, which lasted for thirty minutes, covered the usability of remote sensing techniques, comparison and the features that can be retrieved from the remote sensing data.

Figure 3-3: Focus group discussion with valuers (Source: Fieldwork)

3.3.3. Geodetic Surveying and observation

Field survey using high precision tools such as GNSS (Leica) and tape measure were used to collect field data and reflect the reality on the ground. Four parcels were sampled and surveyed to be used as reference data.

During field measurement, the terrestrial images were acquired, and the images were collected on the basis of the existing and new development compared to the existing data from LAIS database.

Figure 3-4: Field surveying and images acquisition (Source: Fieldwork)

3.3.4. Literature review

A literature review was used to collect the secondary data through internet, books, journals, and reports on valuation for taxation, laws, policies and standards. The reviewed documents such valuation for taxation report, laws pertaining to property valuation for taxation purpose was one to address part of objective 1&2. Literature was useful in this research as after field work the collected primary and secondary data were discussed by comparing the collected data directly to the field and what others researchers wrote on the similar topic.

3.4. Sampling approach

3.4.1. Interviewee sampling

Kumar (2011) explain sampling as a process of picking out a few (a sample) from a larger group (sampling population) to come to the basis for forecasting the occurrence of an unknown of information, situation or conclusion regarding the bigger group. Bhattacherjee (2012) describe expert sampling as a method where respondents are selected in a non-random approach based on their expertise on the subject being studied. The experts sampling method was adapted in this research for selection of the respondents. Respondents (interviewee and focus group discussion) were sampled from different organisations including Rwanda Land Management and Use Authority (RLMUA) former RNRA, Private valuer from Institute of Real Property Valuer (IRPV), Rwanda Revenue Authority (RRA) tax collector and assessor and the district as it can be seen in Figure 3-5.

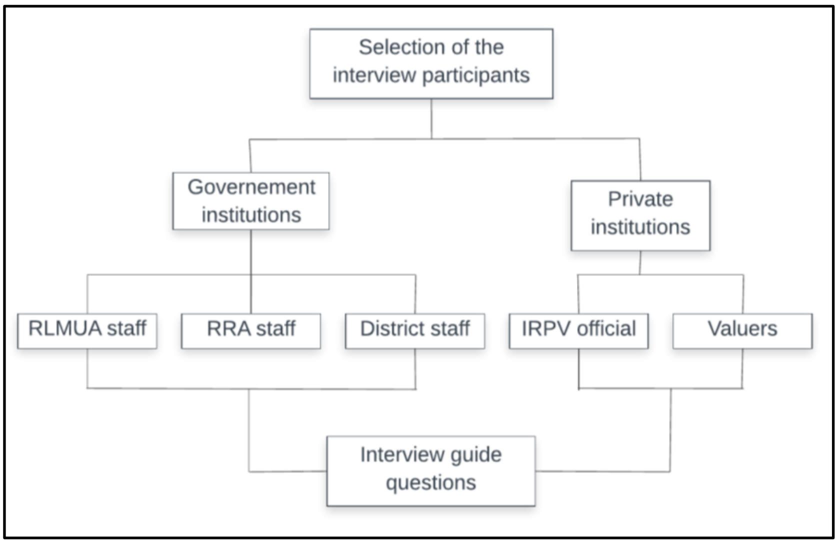

Figure 3-5: Flowchart showing the respondents staff from different institutions

3.4.2. Sampling of the surveyed properties criteria during field surveying

Table 3-2: Criteria of sampled and surveyed properties

Sampled property	Criteria
Property 1	- Accessibility - Clear boundary - Developed land - Visibility of building footprint - To visualise the changes from aerial orthophoto and satellite images
Property 2 **Property 3** **Property 4**	- Accessibility - Existence of the property in all used dataset (remote sensing data) - Developed land - Visibility of building footprint - To visualise the changes from aerial orthophoto, satellite images and UAV

The table above shows the criteria based on to select the four sampled properties in the used datasets.

The Figure 3-6 below describes the process of selecting the surveyed properties during fieldwork. The property was selected from the used dataset as described in Figure 3-8.

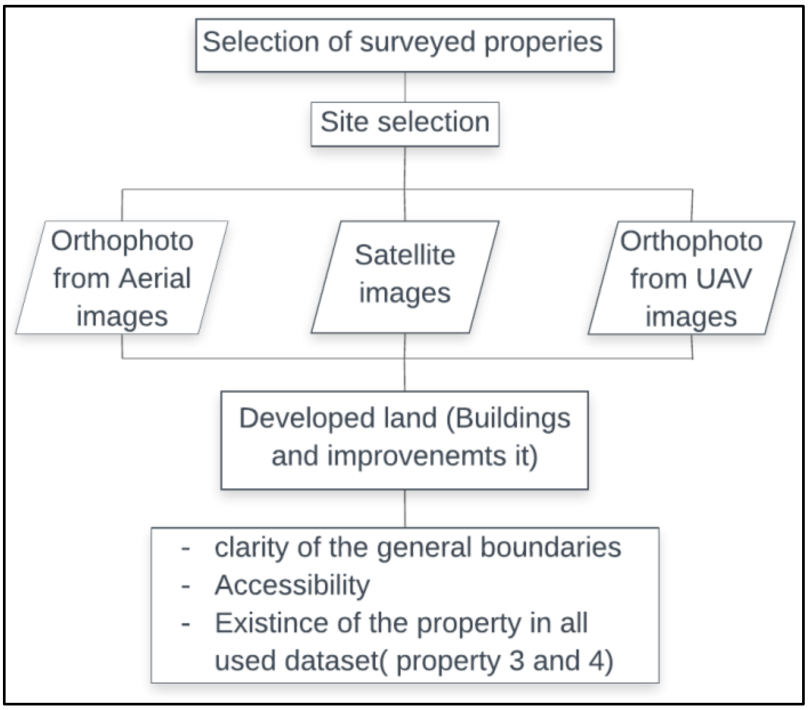

Figure 3-6: Sampled properties surveyed process

3.5. Research Matrix

The following table summarises the research objectives, research questions, methods of data collection, required data and anticipated results

Table 3-3: Research Matrix

Objectives	Research question	Methods	Required data	Anticipated results
To review the current property valuation and taxation system in Rwanda	What are the laws, regulations, policies, challenges, and stakeholders involved in property valuation for taxation in the current valuation methods in Rwanda? What are the policies, regulations, limitations, and challenges regarding usage of remote sensing data for Property valuation for taxation in Rwanda?	Literature review Interviews	Literatures (Laws, policies, regulations, standards, Government reports) Interview transcripts	List of laws, policies, stakeholders, valuation methods and tax collection approach List of limitations of RS technology, challenges, characteristics of existing methods for acquiring data using RS List of policies, laws, and Restrictions on using RS
To develop a new approach for data collection property valuation for taxation in Rwanda using remote sensing data.	What are the procedures or steps for remote sensing data acquisition for property valuation and taxation? What are the remote sensing data requirement for property valuation and taxation?	Literature review Interviews Focus Group discussion	Literature Orthophotos (Satellite, Aerial, and UAV) and terrestrial images GIS software	Developed new approach based on RS data Steps for data acquisition for valuation for taxation purposes List of requirements for valuation purposes
To evaluate the new approach in terms of the developed criteria's for property valuation for taxation in Rwanda	What are the evaluation criteria's for newly developed method using remote sensing data compared to the current Property valuation for taxation approach What are the results of the evaluation of a new developed method based on the remote sensing data? What are its advantages and disadvantages?	Literature review Interviews Focus Group discussion	Images orthophotos Literature Digital camera	Results of new developed methods compared to existing one Recommendation to the new developed method for data collection

3.6. Data Analysis

Qualitative Data was analysed using text-based analysis; the themes were developed and used during data analysis. The interviews and focus group discussions from participants were transcribed and analysed using ATLAS.Ti 8.0 based on the developed themes. Thematic analysis based on the literature review on the factors was used to analyse the collected data. Those themes include (1) factors affecting or influencing the property value; (2) Characteristics of generated orthophotos from remote sensing data; (3) Time/ availability of the platform; (4) Cost of acquiring the data including the cost of hiring the platform. Spatial data were analysed using ArcGIS, and ERDAS Imagine. Through ArcGIS, the comparison of the parcel areas, location visualisation of the subject property and neighbourhood and coordinates comparison were performed. ERDAS was used to visualise and create the area of interest (AOI) in the study area.

3.7. Study area

The study area (Nyarutarama cell-Remera sector- Gasabo districts) was selected based on the previous studies. For example, Koeva et al. (2016); Muneza (2015) and Gevaert et al., (2015). The availability of the remote sensing data such as Orthophoto from aerial UAVs images 2015, satellites images 2013 and Orthophoto from Aerial images acquired 2008. Terrestrial images were acquired during fieldwork using the digital camera.

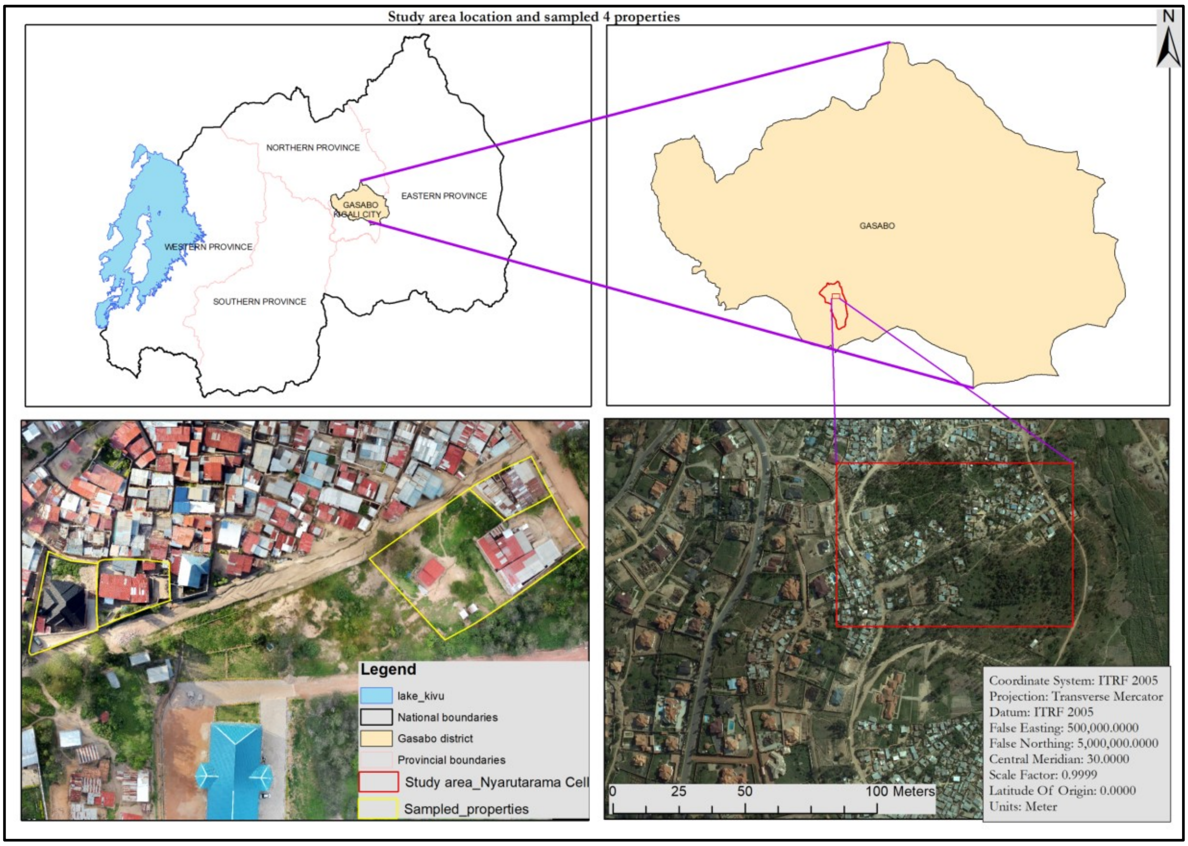

Figure 3-7: Location of the study area

Images Acquired by ITC using Worldview 2 for Kigali and Orthophotos from Aerial images from UAVs particularly at Nyarutarama cell were provided. The orthophoto of 2008 from Aerial images was provided by the Rwanda Land Management and Use Authority. Due to the availability of these remote sensing data in the above area, the study area was selected. Existing remote sensing data were considered and used as secondary data into this research, and the source is specified and referenced.

3.8. Resources required

During this research, the necessarily used dataset is described in Table 3-4 below. The used dataset include Orthophoto from aerial images, Satellite images, Orthophoto from aerial UAVs images and Terrestrial images.

Table 3-4: Used datasets and its source

	Sources	Time		Accuracy		
Dataset		Date of Acquisition	Temporal	Spatial resolution	Radiometric resolution	Spectral resolution
Orthophoto from Aerial Images	RLMU	2008 /2009	-	22cm	8-bit	3 bands
Satellite Images	ITC	2013	1.1day	50cm	16-bit	4 bands
Orthophoto from aerial UAVs Images	ITC	2015	Any time	3.3cm	8-bit	4 bands
Terrestrial imagery	Fieldwork	October 2017	Any time	depends	depends	depends

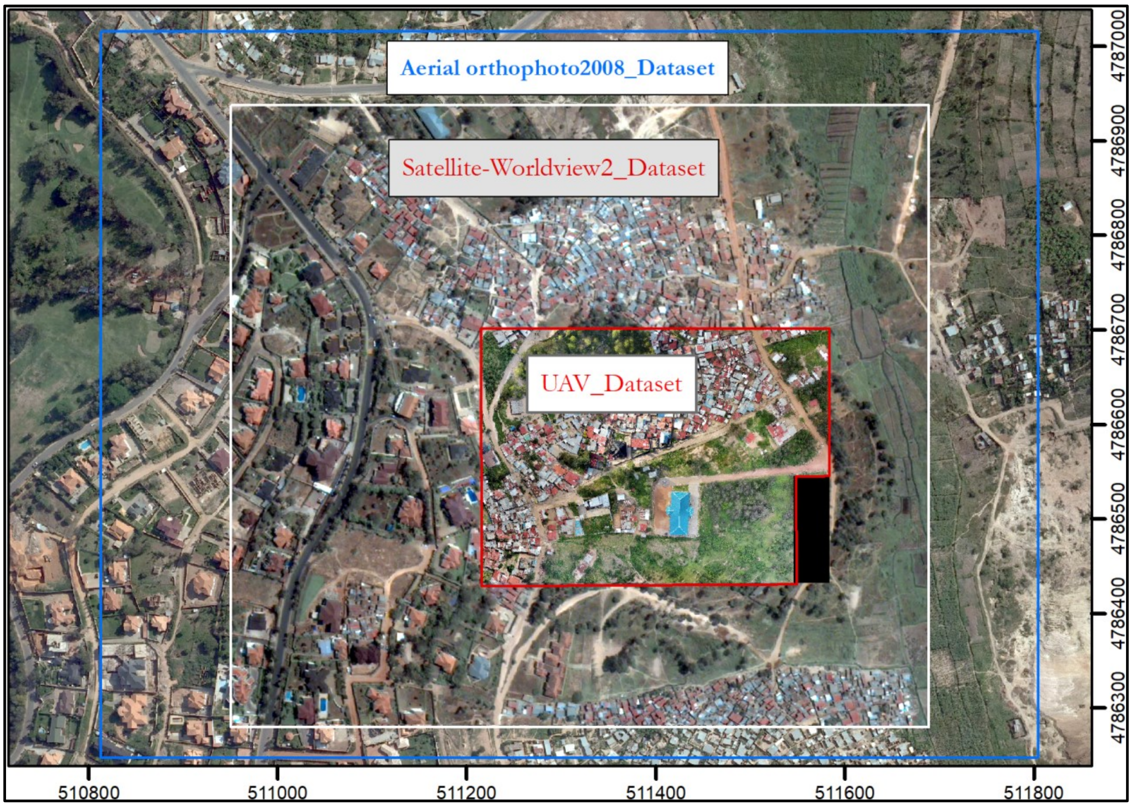

Figure 3-8: Overlap of used datasets in Nyarutarama cell

Hardware and software: Laptop, with ArcGIS, Enterprise Architects and ERDAS IMAGINE, were used to perform different tasks in this research.

4. RESULTS

This chapter presents the outcomes obtained from collected, processed and analysed data using the methods described in chapter 3. The chapter starts by emphasising the current situation of property for taxation system in Rwanda. Further, the chapter gives a detailed account of existing laws, regulations, orders and policies on taxation, valuation, stakeholders, and challenges in Rwanda. The presentation of the findings is done according to the specific objectives. The discussion of the results on the usability of remote sensing data into property valuation for taxation purpose in Rwanda is done in chapter 5.

4.1. Current situation of property valuation for taxation system in Rwanda

In order to answer the research questions of sub-objective one, the current situation of property valuation for taxation system in Rwanda was reviewed. The review framework focused on legal perspectives, involved stakeholders and their responsibilities, data required and existing methods for data collection for property valuation for taxation in Rwanda.

4.1.1. Legal perspectives

Legal documents regulating both property valuation and taxation profession in Rwanda were gathered, reviewed, summarised, and the findings were presented as shown in the following sections.

Legal perspective of real property valuation profession in Rwanda

The real property valuation profession in Rwanda is regulated by the law N°17/2010 establishing and organising the real property valuation profession in Rwanda of 12/05/2010 (which will be referred to as real property Valuation law). The law specifies the structure of the Institute of Real Property Valuers (IRPV) and spells out its preliminary responsibilities. The methods currently used for data analysis also are generally provided by this law, but it does not specify any methods that can be used to collect data for property valuation. Article 27 of real property valuation law, specifies that "*Valuation of any type needs that the valuer applies one or more valuation methods provided by this Law or any other method accepted by the Regulatory Council. The valuer shall select the best valuation method that can be used to determine the fair market value of the real property*" (GoR, 2010). Article no 31 of real property valuation law in paragraph two states that "*Upon approval by the Council, a valuer may use any other relevant worldwide methods not provided in this Law to carry out the assigned work*".

During the interviews with the IRPV officials, two of the three respondents remarked that "*the valuation standard in Rwanda exists as well as practising guide*". However, there is confusion between standard and law as one interviewee highlighted that as there is no valuation standard, to carry out property valuation yet, the international valuation standard is used. It is the responsibility of IRPV to develop the valuation standard, and it requires the approval of the property valuation regulatory council before using it. Through an advertisement issued in 2015 by former Ministry of Natural Resources regarding hiring an international expert to develop the property valuation standards and other guidance related to property valuation in Rwanda, respondents from RLMUA underlined that "*Rwanda property valuation standard is not yet developed*".

Legal perspective property taxation system in Rwanda

Rwanda National Land Policy adopted in 2004 requires that "*land transactions and land taxation should be included in land administration as elements of land development*". The land market gives more value to land and promotes its use in a more productive manner. It facilitates investment in land development and enables various land users to expect better times ahead (GoR/Ministry of Lands, 2004). Law N° 43/2013 of 16/06/2013 Governing Land in Rwanda (Land law) in its Article 43 states that "*a landowner with freehold title* *shall pay property tax as provided for by the law, while landowner with emphyteutic lease shall pay lease fees as provided by a Presidential Order*" (GoR, 2013). The current property tax (fixed asset tax) is governed by the law N° 59/2011 of 31/12/2011, establishing the sources of revenue and property of decentralised entities and governing their management (taxation law). Also by the presidential order N° 25/01 of 09/07/2012, establishing the list of fees and other charges imposed by decentralized entities and determining their thresholds. The current laws related to property tax in Rwanda are categorised in three different taxes as specified by the taxation law and confirmed by RRA and districts interviewed officials during fieldwork include fixed asset tax, land lease fees and rental income (GoR, 2011).

During the interviews, respondents highlighted that "*fixed asset tax or property tax requires valuation report and its taxes are based on the market value whereby the tax value is equal to 1/1000 of the open market value of the property*". The Ministerial order Nº005/12/10/TC of 22/06/2012 determining the modalities for the implementation of Law nº 59/2011 of 31/12/2011The Ministerial order Nº005/12/10/TC of 22/06/2012 determining the modalities for the implementation of taxation law specifies the process and suggests the steps to be followed by the taxpayer for all types of taxes. The steps and key actors involved in property tax (fixed asset tax) are described in Figure 4-1

4.1.2. Current institutions/stakeholders involved in property valuation for taxation system in Rwanda

There are different stakeholders involved the process of property taxation. These include such Rwanda Revenue Authority (RRA), districts, and taxpayers, Rwanda Land Management and Use Authority (RLMUA), Valuers, Institute of Real Property valuers (IRPV), Rwanda Development Board (RDB). The Figure 4-1 below summarises the current process for collecting fixed asset tax (property tax). The list of stakeholder and their responsibilities is attached as an appendix 1.

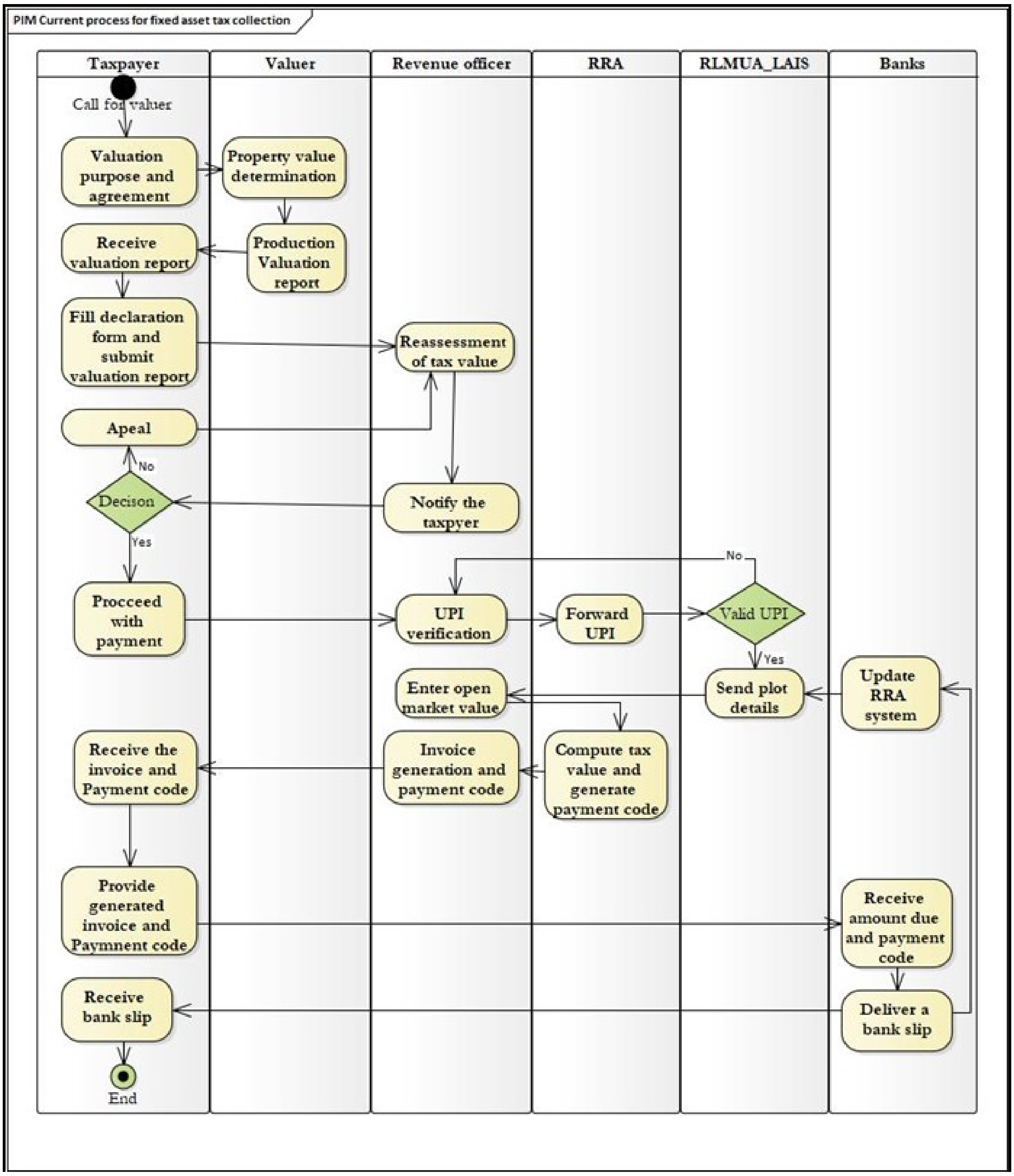

Figure 4-1: Flowchart for current property tax system in Rwanda

4.1.3. Required data for property valuation for taxation purposes in Rwanda

The required data for property valuation for taxation purposes depends on the type of the property and its use. The most important requirement is the land ownership titles (lease or freeholds). A Land title is the one that shows the ownership type (whether it is under leaseholds or freeholds titles). Taxpayers with freehold title require valuation report as tax basis calculation. The necessary information required to value the property for taxation purposes as said by participants include "*land certificate ownerships, Built-up area, technical conditions of the property, constructions materials, infrastructure attached to it, land use*". Most of the information is collected from the field, and others are retrieved from the land title (LAIS database).

Table 4-1: Required data and where can be collected

Required data	Fieldwork	Land title LAIS	Masterplan	Google Earth	Valuers	Estate agencies
Parcel area	✓	✓				
Current Land use(on title)	✓	✓				
Built-up area	✓					
Construction materials	✓					
External works	✓			✓		
Status of the property	✓					
Infrastructure attached	✓			✓		
Planned land use		✓	✓			
Sales comparable		✓			✓	✓
Location	✓	✓	✓	✓		

The taxes for leaseholders do not require a valuation report. All the required data for tax calculation is based on Unique Parcel Identifier (UPI) which is obtained from the land lease title and district council resolution. The tax value is based on a rate per square meter rather than on the open market value. Thus, fixed asset tax (property tax) is based on the open market value and requires "*sales contract value or certificate of valuation by the certified valuer to fix the open market value*". The most highly trusted sources of the required data, as discovered during the fieldwork include RLMUA, estate agencies, and valuers. However, the quality of RLMUA data appears to be incomplete, inaccurate and outdated in some cases. Focus group participants confirmed this, stated that "*the land use on the title differs from land use on the ground, the size of the parcel on the ground differs from those are in the system or title, while the number of houses within in parcel is missing from Rwanda land cadastre.*"

It is still a challenge in Rwanda to get all required data for the valuers to support their value assessment. During the focus group discussion, the valuers highlighted that "*valuation depends on the available data, purposes of valuation and use of the property*". For instance, for the income generating properties, valuers need to look at book account and see the income the property is generating. The property value is calculated by capitalising of the future income from that property. Thus, many valuers depend on the property used to assess its value. These also were confirmed by participants from focus group discussion shared that "*lack of the data to use the appropriate methods to value the property according to its type, this resulted in the application of replacement cost method being used more compared to others methods of property valuation*".

4.1.4. Current data collection methods and steps for property valuation for taxation purposes in Rwanda

The current methods and steps being used to collect the data for property valuation for taxation purposes in Rwanda as highlighted by respondents that "*generally, methods of collecting data for property valuation for taxation in Rwanda are same as other methods for any property valuation purposes*". The current approach being used in general is classified into three main methods which include "*Field visit (inspection of the property), Google Earth, and Masterplans".*

1. Field visit inspection

During field visit an inspection of the site, the valuer has to use different methods and tools for data collection for property value determination such as "*Tape measurement, Digital camera, and handheld GPS and laser distance meter*".

i. Tape Measurement

Whilst the tape measurement is usually used for buildings and improvements; the parcel areas are obtained from the land title. Throughout focus group discussion, the participants underlined that tape measurement is used to "*measure the size of the houses, gross floor area, improvement and other external works such as drainage system, parking, gardening*" to complete data from land titles (LAIS database).

ii. Digital Camera

The camera is used to take pictures, to "*ensure that the property exists at the date of inspection and to have a better visualisation of their physical appearances, the materials and technical conditions of the subject property to be valued*" as highlighted by the valuers during the focus group discussion. Acquired images are used in property valuation as a source of information and prove its existence at the date of valuation.

iii. Handheld GPS

Currently, Rwandan valuers use handheld GPS to verify the location and measure the property to be valued. This technology is used for determination of positions of the property. During the interview and focus group discussions, the respondents said that "even if handheld GPS is being used in data collection, its accuracy is not good as such should be". As property valuation needs the updated and accurate information, the handheld GPS currently used has 3m of accuracy.

iv. Laser distance meter

Laser distance meter is used to measure the internal and external parts of the buildings. According to the users, this tool is more precise, and measurements can be done faster than with tape.

2. Google Earth

Google Earth is used for location, verification and visualisation the existence of the property at that parcel and confirms their existence on the ground at the date of valuation (Figure 4-2).

Figure 4-2: Property location visualisation-Google Earth (Source: Valuation Report Nzakamwita, 2017)

3. Masterplan

The master plan is one of the districts' planning outputs, and it is prepared for a period of 10 to 20 years. The master plan is used majorly in urban areas to help valuers to know the allowed land use and zoning of a particular area.

As shown in Figure 4-3, the current steps involved in carrying out property valuation for taxation purposes in Rwanda was summarised such as a call from the client (taxpayer) or tender bid advertisement of institutions (Private, Public or NGOs). During this phase, an agreement negotiated between taxpayer is done (oral or written). After the agreement is done, the next step is to conduct field inspection for fieldwork. The field inspection has to be conducted by the competent valuer in the presence of the landowner. If the valuation is for developed land, measurements of the buildings, improvement within the compound of the parcel are required. While for undeveloped land, the information provided on the land title is used unless there are unreported changes on the land itself. During fieldwork, the valuer has to collect the required data for valuation, and some pictures are taken for further analysis. The office work consists of analysing the collected data and report preparation is done. As a result, the validated valuation report is provided to the taxpayer. Updating of the valuation report also follow the same steps, unless if there are no changes to the property done. However, the valuer should be well informed that there are no changes happened in four years.

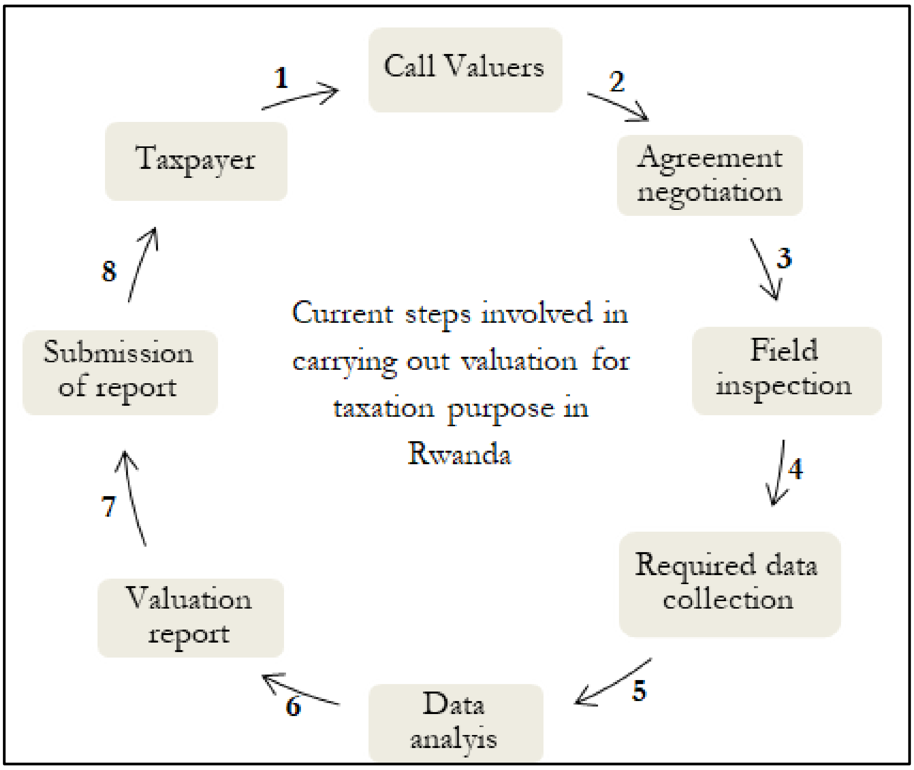

Figure 4-3: Process cycle and steps for current valuation system in Rwanda

4.1.5. Type of property taxes in Rwanda

Three types of property taxes were revealed as levied on property in Rwanda such land lease fees, rental income taxes and fixed asset taxes (interview with district and RRA officials). The difference between these types of three taxes is based on the land tenure type. Land lessee fees are the tax levied from leaseholder; freeholder pays fixed asset tax and rental income tax can be levied on both land tenure regime. All these taxes are levied on an annual basis. The only type of tax requires valuation report is fixed asset tax as it is based on open market value. According to the LAIS records, the land lease ownership is more dominant compared to freehold ownerships with 97.8 % of the registered parcels are under land lease regime and remaining 2.2% is under freehold regime (Figure 4-4).

a) Land lease fees

Land lease fees are paid annually. The method used to determine the tax value is based on the rate per square meter or hectare. The rate is determined by district council depending on the infrastructure and development in an area. The presidential order determining the list of fees and other charges levied by decentralised entities and determining the thresholds in its article 9, states that "*Any person owning land and holding a land lease certificate issued by the competent organisation shall pay an annual land lease fee based on the square meter or hectare*". The same article declares that it is the responsibility of the district council to determine the fees to be paid annually based on the available infrastructure in the particular area where the land is located and its use. The thresholds of land lease fees rates are arranged from 30 Rwf (around 0.03 euro) to 80 Rwf (0.08 euro) per square meter and (4000 Rwf) per hectare levied from agriculture and livestock land with more than two hectares.

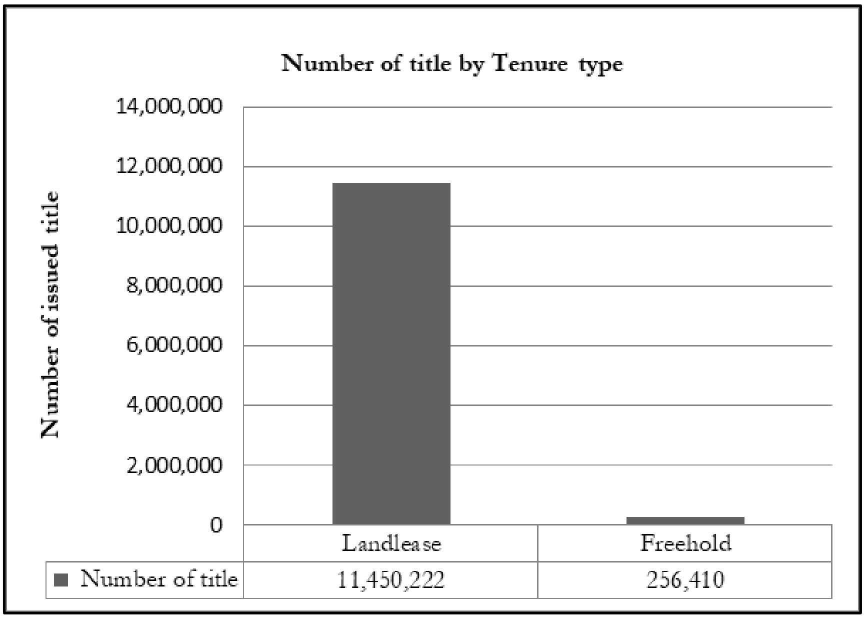

Figure 4-4: Number of titles by Tenure type (RLMUA, 2017)

b) Rental income taxes

Rental income tax is a tax imposed on individuals who earn income from the rented immovable property. Taxes are paid annually based on rental fees the landowners collected from the tenants and this tax also paid in terms of percentages of generated income from the property after deduction of the expenses. According to taxation law articles 50, states that the expenses should be 50% of the generated income per year. The tax rate is range from 0-30% depending on the generated income. The more income generated, the more rate is applied.

c) Fixed asset taxes

Fixed asset tax also called "*property tax*" is a tax that imposed on immovable property with freehold titles. Through interviews from district and RRA officials, they highlighted that "*property tax requires valuation report as it is based on the open market value that why they require an expert in valuation to determine the open market value*". Fixed asset tax value is normally based on the value of the property. The rate that applied to the value is fixed at a thousandth (1/1000) of the taxable value per year. During fieldwork, interviewees underlined that "*they are still facing a problem of taxpayers who declare the property and hide some information related to their property for instance when they have a number of buildings within few parcel because the purpose is for taxation they undermine the value, they can report only one building*". However, the mechanism of monitoring changes on the ground is needed so that taxpayers do not hide some information can be captured easily.

Fixed asset taxes value can be updated once in four years as stipulated by the taxation law, in its article 15. However, in case, there are some improvements and changes made to the property the taxpayers required an updated valuation report (new self-assessed tax) and fill a new tax declaration or assessment notice (GoR, 2011). Interviewees highlighted that "*in case of property is residentially used, the fixed asset tax value should be determined after deducting the amount equal to three million (≈3000 €) on its market value*". Also, it is specified in the taxation law, in its article 18 on the tax exempted for property taxes point number 8.

4.1.6. Usability of remote sensing data in Rwanda

Remote sensing has been used in Rwanda for the land issue since 2008. During the interviews, findings show that in public institutions such RLMUA, remote sensing data are used mainly in Land cadastre system. Interviewee highlighted that "*the Rwanda land cadastre was build based on the high-resolution orthophotos captured in 2008 using Aircraft and Satellite images. Especially Satellite images were used in the North-western part of the country due to the topography of that area it was not able to cover that area using Aircraft*". The generated orthophotos were very useful in identifying entire properties. Given that the images of 2008 are becoming outdated, the valuers often overlaps the satellite images with the latest version of Google Earth image for valuation purposes and visualise the location and update the information on the ground.

Remote sensing data is very important during the initial phase of data collection and updating the spatial information. Thus, Rwanda has been using the orthophotos of 2008, generated from Aircrafts images, answers on the issues of updating the existing spatial data there was a plan to update this information. One interviewee highlighted that "*the Update cycle was planned based on two context namely urban areas and rural areas*". The update cycle for urban areas especially Kigali city had been set at five years, and ten years for rural areas. However, funds constraint have meant that this has not been adhered to, demanding the use of open source data such as satellite images from Google Earth, USGS and others to complement existing data. It was planned to do another aerial photogrammetry campaign for images acquisition for updating purposes.

Acquiring new images requires hiring an international photogrammetric company that has the right to fly aircraft and produce the updated aerial images and orthophotos. Nevertheless, satellite images from Google Earth are used as additional source of information to update the outdated information. Physical field surveys using high precision tablet or GNSS with a combination of established reference stations for better accuracy are used to update existing spatial information.

Rwanda Land Management Use Authority as a government institution in charge of spatial data, the issue of spatial accuracy it is their ambitions to have the high spatial resolution images to gain the details from the field compared to the existing data. Currently, the government of Rwanda has signed the "*Memorandum of Understanding with the government of Gabon under which both governments will be sharing spatial information and expertise in land registration*" said by the interviewee. Government of Gabon will be providing satellite images as they have satellite centre, while the government of Rwanda will be providing the expertise in land registration using fit-for-purpose approach. The interviewee shared that "*generally, the usability of remote sensing data in Property valuation for taxation purpose is at very low for instance the most used images are those captured during the field work and those images that can be downloaded from Google Earth. Thus those images got from Google Earth they do not know which remote sensing techniques used to capture them and therefore their spatial and temporal resolution is not were recognised*".

4.1.7. Limitations and challenges to using remote sensing data into Property valuation for taxation

The general finding from interviews and focus group discussion is that the most challenges are lack of the data and cost that are needed to get the remote sensing data, skills to use these remote sensing platforms. The issue of funds comprises everything due to lack of funds available. Another limitation relates to laws and regulations. In Rwanda, there *are no specific laws or regulations governing the use of remote sensing tools* highlighted during the interview session. The use of remote sensing tools is governed by the law regulating the Civil Aviation in Rwanda. Availability of the platform it is another challenge emphasised by the interviewees because they have to be ordered outside of the country. During interview discussion with Ministry of infrastructure official highlighted that "*only one company has been registered and has the right to fly UAVs but for other remote sensing techniques their need to be hired from international companies to carry out the services of photogrammetry and another process until final products*".

4.2. Developed UAV-based method for data collection for property valuation for taxation in Rwanda

Figure 4-5 below, shows the general boundary visualisation of sampled property number four (selected based on the criteria shown Table 3-2) in the different remote sensing datasets at the same scale (1:700). The results show that the features on UAVs-orthophoto in Figure 4-5 (a) are more visible than satellite and aerial orthophoto as shown in Figure 4-5 (b) and (c). However, from the satellite-Worldview 2, the general boundaries cannot be differentiated from other features while for aerial orthophoto; it is less visible compared to UAVs-output. The construction materials such as roof cover and pavement or external works can are visualised correctly in (a) but also less from (b) and type of roof can be described. The characteristics of the generated orthophoto and raw images are essential in terms of property valuation. UAV has more accurate information compared to others used remote sensing in this research.

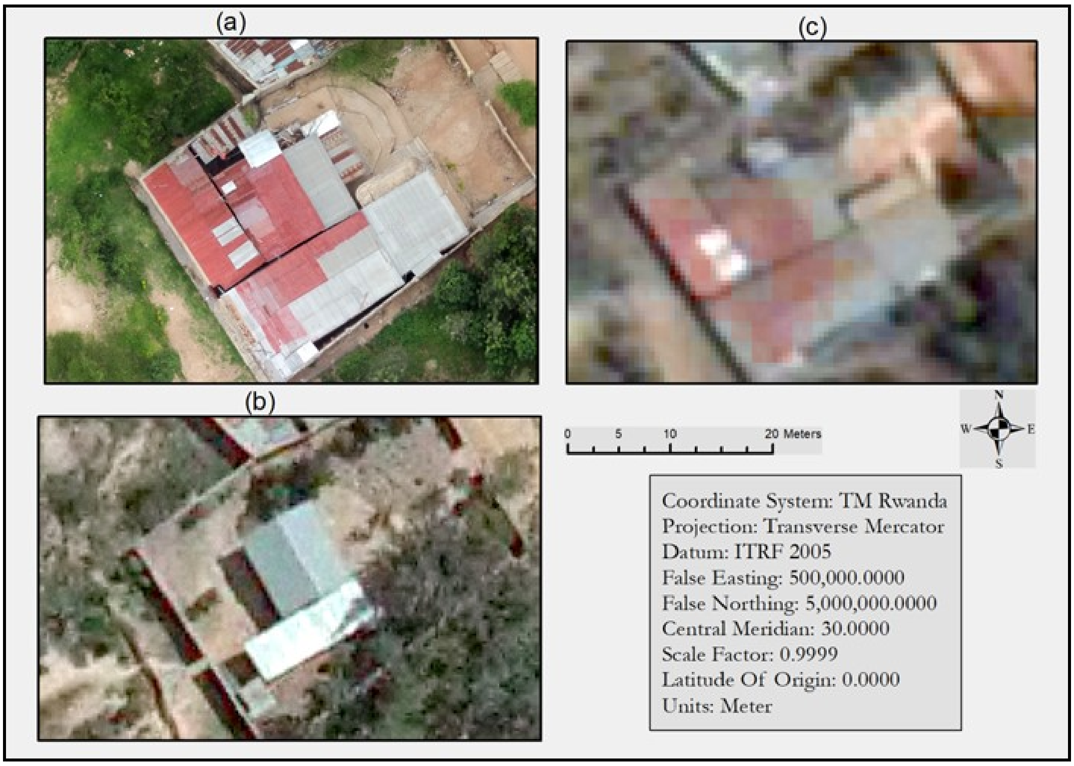

Figure 4-5: General boundary visualisation from 3 used dataset: (a) from UAV, (b) from Aerial orthophoto and (c) from Satellite-Worldview 2

Based on the comparison described above and in section 2.4 (chapter 2) of this thesis, the results show that UAVs is most beneficial for property valuation for taxation purposes. The new developed method for data collection using remote sensing data is based on UAVs. UAVs-based approach for data collection for property valuation for taxation purposes was developed based on the reviewed similar workflows, interviewees' suggestion and adapting them to the context of Rwanda. Figure 4-6 below describes the process of developed methods for property valuation for taxation.

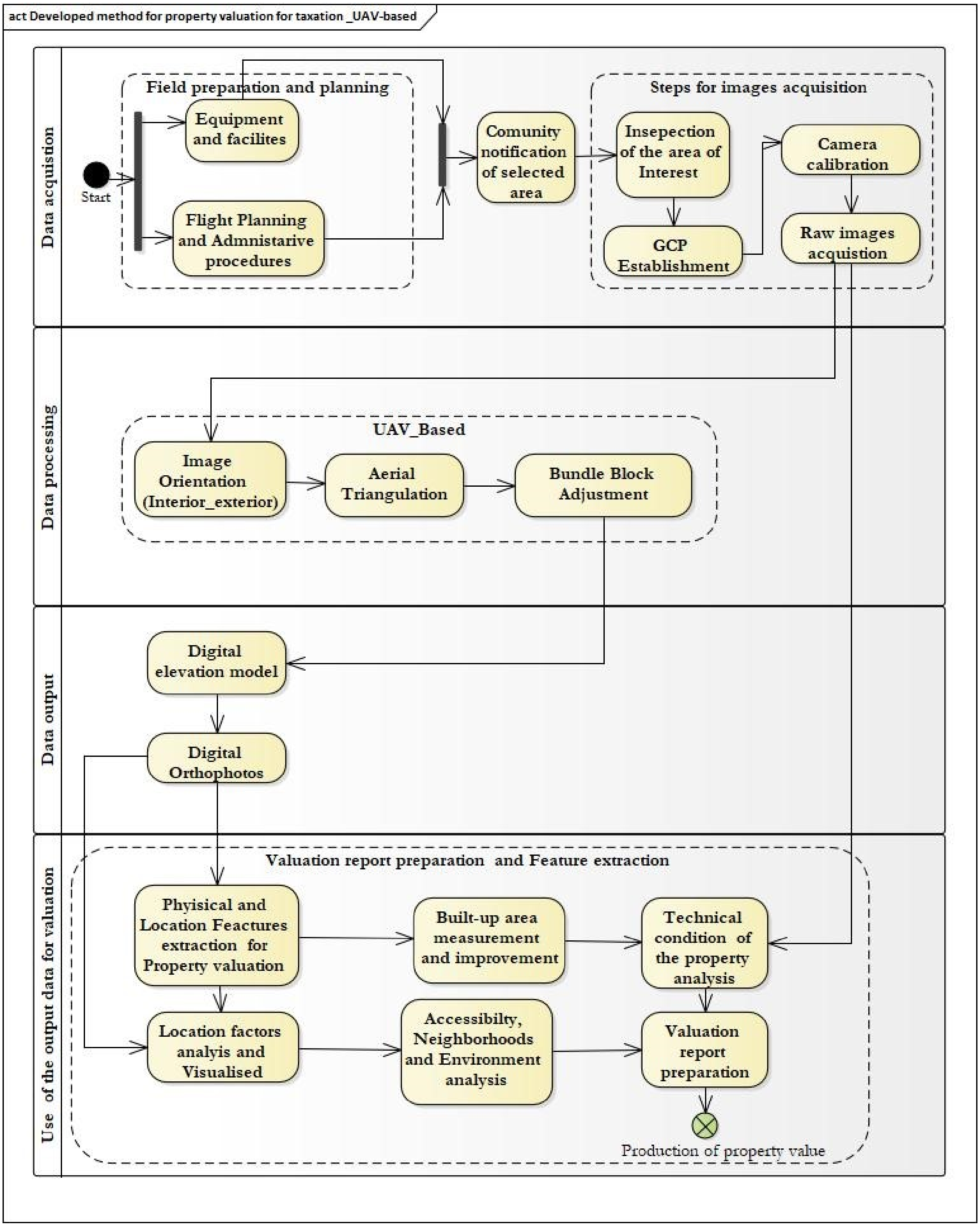

Figure 4-6: Flowchart of the developed UAV-based approach for data collection for property valuation for taxation purposes

The steps described Figure 4-6; include data acquisition which involved field preparation and planning, community sensitisation, images acquisition; data processing; the generated output and Use of the output data for property valuation. The produced orthophoto and acquired raw images serve as input for property valuation for taxation and updating the spatial information and improvement on land.

4.2.1. Data Acquisition

For each surveying project using UAVs or traditional method for data acquisition, the initial stage is to start with field preparation and planning. Field preparation involves gathering materials and equipment facilities required to execute the task. During this phase, proper planning according to the legal requirements regarding the use of remote sensing data should be done. UAVs require actions, such as flight permission, software selection, selection of an area of interest, ground sampling distance (GSD), among others. The detailed analysis of the project settings such as accuracy needed, image overlap should be done. The community of the selected area of interest has to be informed about purposes of the project. The acquisition should be done by the eligible company to fly UAVs according to the regulatory framework. Before image acquisition, to have accurate orthophoto production camera calibration should be checked and measurements of Ground Control Points (GCPs) on the ground with required technical equipment should be done. Therefore, after flight planning the acquisition of the raw images is done with UAV. The quality of produced Orthophoto depends significantly on the quality of acquired images.

4.2.2. Data processing

The acquired raw images must be processed using specialised software such as Pix4D. In order to generate the final outputs such as Digital Surface Model (DSM) and Orthophoto, the procedure that needs to be followed include image orientation, Area Triangulation and Bundle Block Adjustment. For image orientation, interior and exterior orientation should be done. Interior orientation, (IO), define the position of the projection Centre of the camera concerning the image, the focal length and lens distortion. While exterior orientation, define the position of the camera projection Centre and rotation of the assembly of its optical axis concerning the mapping frame (U0, V0, W0, χ, φ, ω). For Area Triangulation, the combination of GCPs with the metric sensor parameters, and then applies precise photogrammetric measurements to accurately georeferenced the imagery should be done. The automatic tie points can be generated. The accuracy and consistency of the aerial triangulation process affect all subsequent mapping tasks. Bundle Block Adjustment consists of defining the mathematical relationship between the images and contained within the block, the camera model and the actual ground. Hence all post-processing procedures should be done by practised experts working in a photogrammetric firm.

4.2.3. Output generation

There are two main outputs such Digital Surface Model (DSM) and orthophoto. The generated orthophoto can be used as input for property valuation for taxation. As property valuation requires the updated information, this data can be retrieved from the generated orthophoto. As shown in Table 2-1 of this thesis, generated orthophoto should be a source of data for property valuation for taxation.

4.2.4. Use of the output data for property valuation for taxation

The raw images and generated orthophoto from UAVs can serve as a source of data for property valuation as it contains the necessary data (Table 4-2). High-resolution images acquired by UAVs can be used for identification and determination of the exterior technical condition of the property and its improvements. With a high resolution of raw images, the information such roof materials, technical condition and property and its construction materials can be identified and visualised. Identification and determination of physical attributes of the property in valuation process is an essential component to determine the property value

Table 4-2: Physical attributes of the property that can be retrieved from UAV raw images and generated orthophoto

Datatype	Building						Land						
	Area	Localization	Neighborhood	N0. of floors	Fittings	Tech. condition	Area	Localization	Neighborhood	Shape	Type	Development	Utilities
Orthophoto	+	+	+	+/-	-	+	+	+	+	+	+/-	+	+
Raw images	-	+	+	+	+/-	+	-	+	+	+	+	+	+

As shown in above Table 4-2, it can be noted that the orthophoto and raw images acquired from UAV are useful in determining some of the physical and locational characteristics of the property and its improvements. Based on the orientation of the camera (inclined or oblique) during image acquisition, information on the technical condition of the property such as facades of the buildings and constructions materials can be obtained. The visualisation of such information enables valuers to remotely evaluate the physical obsolescence of the property with high precision. Apart from qualitative data on the taxable property, the quantitative data such as parcel area, built-up area, perimeter and distance to public facilities can be determined from generated orthophoto.

Table 4-3: Physical characteristics of property identifiable on UAV-Orthophoto for sampled property 1 and 2

Property (Land or Buildings)	Physical factors					Location factors				
	Parcel area (m²)	Built-up area (m²)	Improvement (m²)	Shape	Type	Neighborhood	Accessibility	Land use	Environment	Utilities
Property 1	708	275	282	regular	built	yes	yes	-	yes	yes
Property 2	557	247	175	regular	built	yes	yes	-	yes	yes

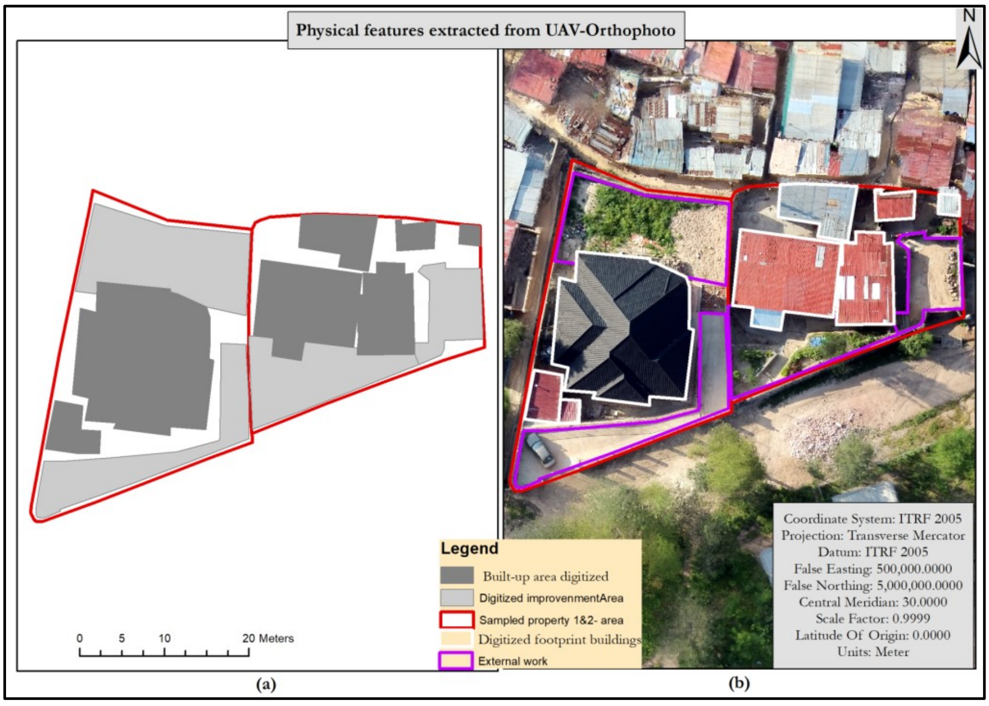

Figure 4-7: Feature extracted from UAV-Orthophoto (a) and overlaid them to UAV-Orthophoto (b)

4.2.5. Terrestrial images

The terrestrial images can be acquired using a non-metric digital camera. After the acquisition of the terrestrial images using a digital camera, image processing is required. There are variety of software to process and analyse the acquired raw images. The generated output especially 3D modelling can be used to measure the height of the property, and the number of floors can be determined. The physical appearance of the property can be described from the 3D model made by terrestrial images (Figure 4-8). Which can provide additional information that can be beneficial for property valuation for taxation purposes. Such information can be considered as an important factor for change of the price of the property. Example can be legal or illegal extension of the property size or condition

Figure 4-8: Generated 3D model from terrestrial images showing that from the model the height of the building can be measured

4.2.6. Comparatives elements

The comparative elements were used to compare the different information that can be retrieved from remote sensing data. Factors influencing the property value were used. Moreover, these factors are classified into two main categories such as *internal factors and external factors* (Figure 2-1). Internal factors include parcel size, built-up area; improvement; interior design and type of the subject property whereas external factors include accessibility, neighbourhood, land use, Environment and Utilities.

a. Internal factors

1. Parcel size

The size of the parcel is used to determine the land value of either the developed or undeveloped parcel. This serves as the tax base for both leaseholder and freeholder. Moreover, for the land lease fee to be paid by the taxpayer parcel size play a very important role because the bigger the parcel, the more lease fee is paid if the location of the parcels are in the same areas whereby the rate is the same. Parcel area serves as land lease fee basis as the method of determining the lease fee is the rate per square meter. Additionally, for the property tax where the parcel is not developed the open market value is determined based on the rate per square meter. However, the used rate for lease fees and market value differ. The last one must be determined by the private valuers on the basis of recent sales, location and infrastructure within the area and public facilities surrounding the areas. During the focus group discussion, the valuers revealed that the sizes of many parcels in LAIS database-records are not same compared the ground truth. For instance, some can have bigger size on the title (LAIS-database) compared to the actual size on the ground. However, valuers highlighted that "*there is a challenge as a valuer cannot have the solute to say look, this parcel is 489 m² and on the ground is a 557 m², and my valuation is going to consider ground truth a 557 m² as it is*".

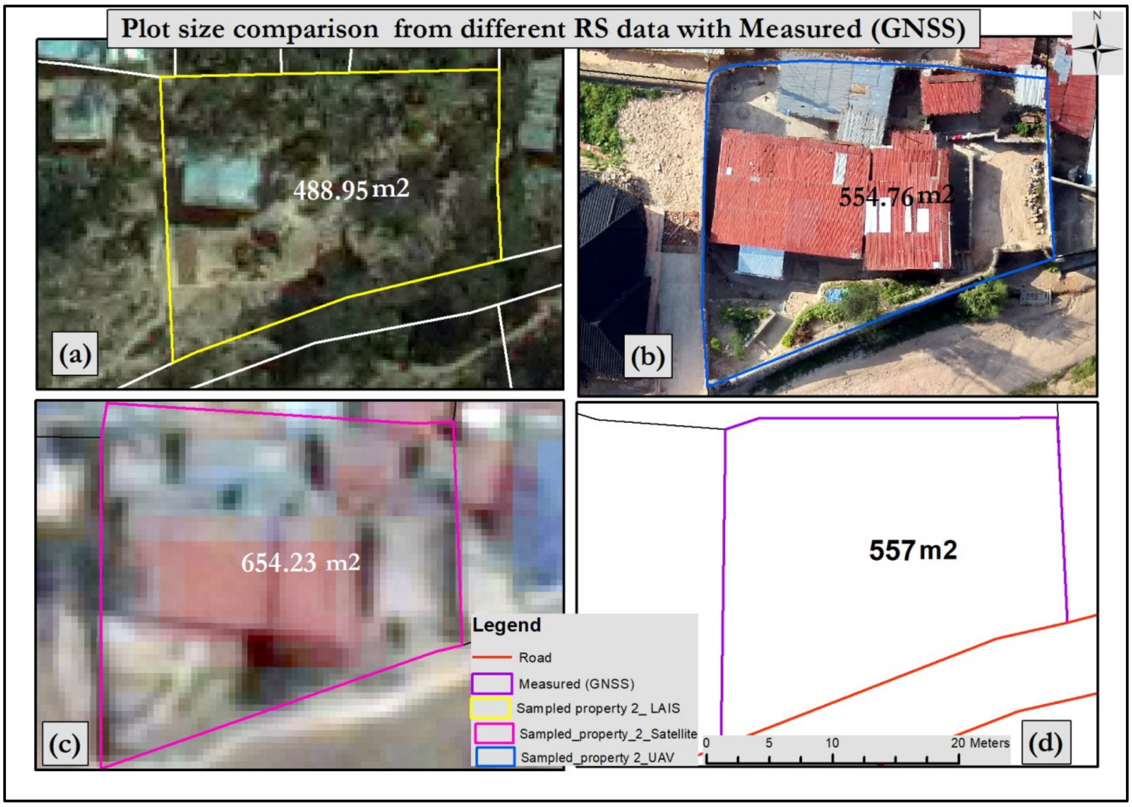

Figure 4-9: Parcel area comparison of sampled property two from different remote sensing data: (a) existing parcel area in database (Source: RLMUA, 2017), (b) manually digitized from UAV-orthophoto (Source: ITC, 2017), (c) manually digitized from Satellite (Source: ITC, 2017) and (d) measured from the field (source: fieldwork)

The only thing that the valuers do is to report to whoever is intending to use the valuation report, where the size on the title is not reflecting the actual size on the ground. This is because of the power of the land titles; the size on the land title has been used as land value basis. The authority who is intending to use the report has to decide on the above-reported errors if they think is too big the procedures of titles correction will be procced before valuer can revalue the property and reflect the actual size.

As shown in Figure 4-9, the comparison results of parcel size revealed that, parcel area manually digitized from UAV-orthophoto (b) is closer to the area measured with GNSS (ground truth) compared to manually digitized from satellite images(c) and existing area in LAIS database which is based on the orthophoto (a).

2. Built-up area

The built-up area is most relevant to property tax system. Property tax is imposed on the basis of market value and this involved of the value of the land, building and improvements. Building and improvements being part of the market value of the subject property require their size and level of coverage in that area. With a built-up area, the total gross floor area can be determined; the volume of the properties also can be determined by multiplying the height of the property to its built-up area. The participants from focus group discussion underline that "*due to the lack of data especially related to buildings and improvements; the fieldwork measurement and image acquisition are compulsory as the current property tax regime is based on open market value, and it depends on the determined information from the field*". The purposes of acquired images are to show the existence of the property and are also used to visualise technical conditions and the physical appearance of the property.

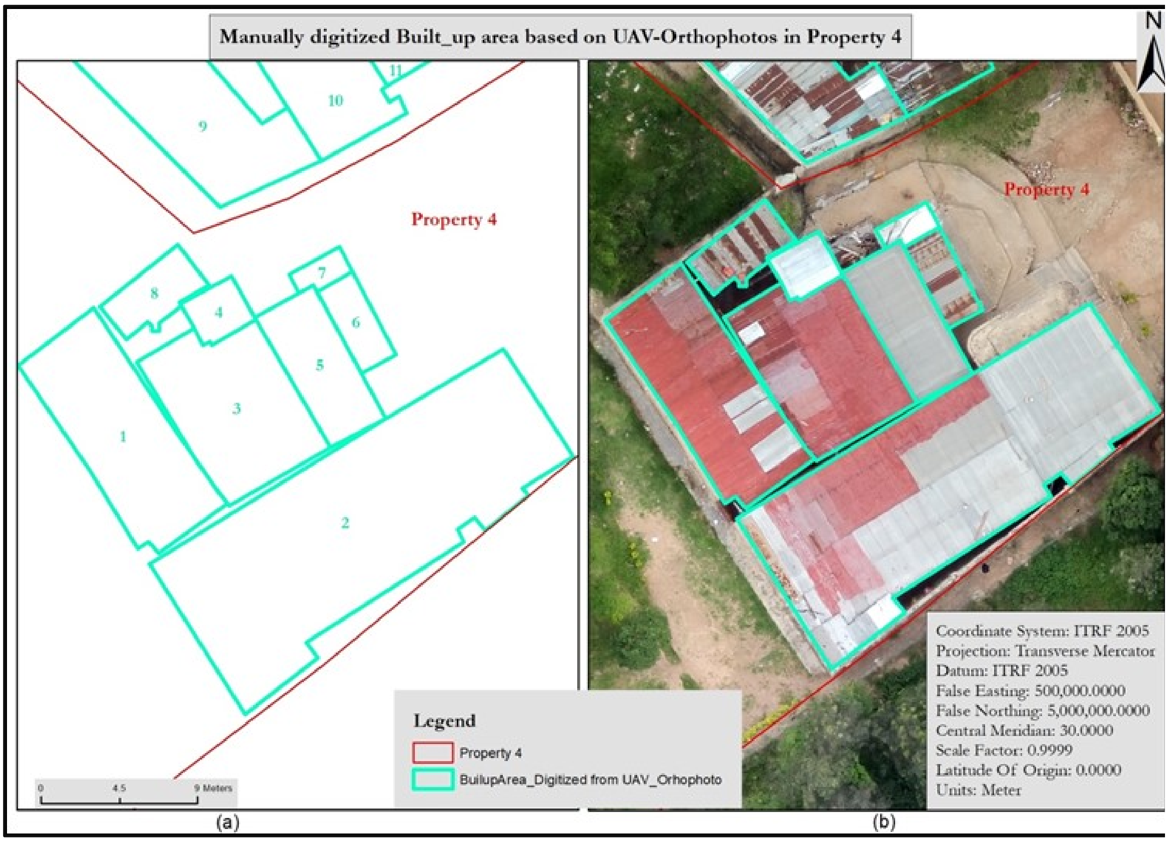

Figure 4-10: Digitized buildings footprint from UAV-Orthophoto of property 4 (a) footprint outlines overlaid on the UAV-Orthophoto (b)

Table 4-4: Manually built-up and parcel area digitised from UAV orthophoto of sampled properties 3 and 4

	Physical factors					Location factors				
Property (Land or Buildings)	Parcel area (m^2)	Built-up area (m^2)	Improvement (m^2)	Shape of parcel	Type	Neighborhood	Accessibility	Land use	Environment	Utilities
Property 3	399	263	-	regular	built	yes	yes	-	yes	yes
Property 4	2471	417	278	regular	built	yes	yes	-	yes	yes

3. Improvements or external work

Improvement refers to the level of external works done to increase the value of the subject property; these include property maintenance, concrete parking, gardening, sewage drainages system, water tank, and other. These features are also part of the market value of the property to be taxed and need to be assessed and considered during data collection for property valuation for taxation purposes. The size of these external works is required. However, they are not recorded in land cadastre, but remote sensing data can be used to capture them. As shown in Figure 4-11 using for example UAV orthophoto, external work (improvements) related with properties can be digitized.

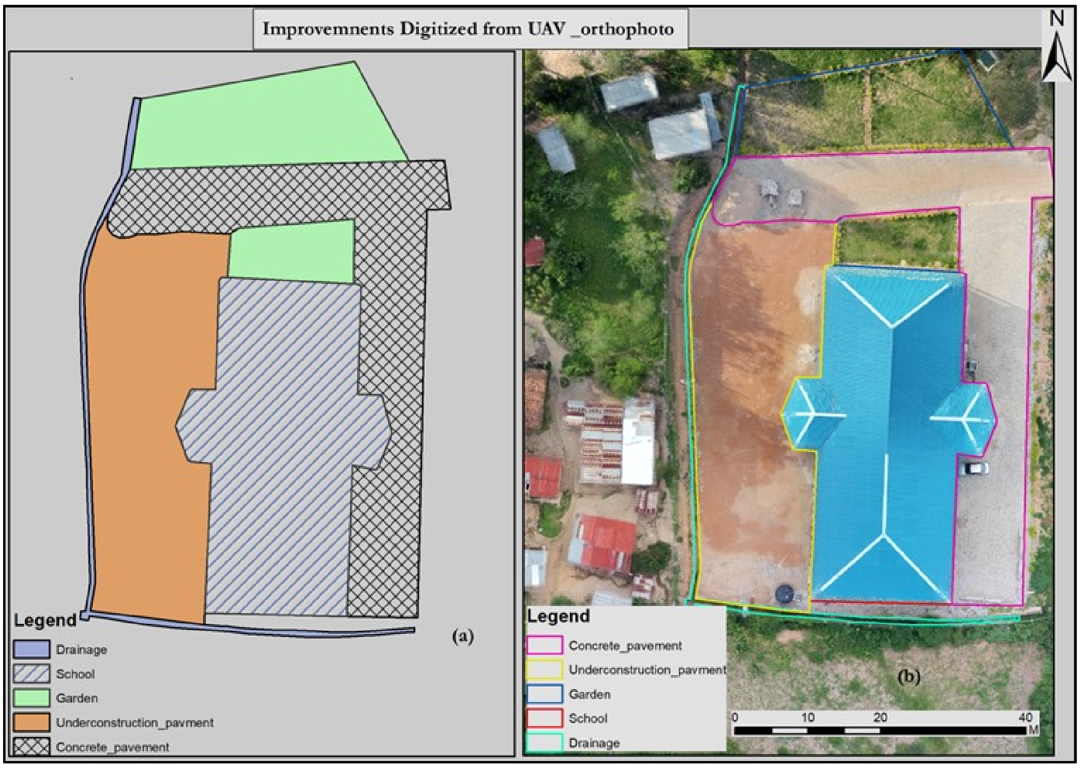

Figure 4-11: Improvements digitised-manually from UAV-orthophotos (a) and (b) over layer them into UAV for visualisation

A combination of some remote sensing techniques can also be beneficial. For example UAVs and terrestrial images can be combined. These two techniques can provide quite detailed information valuable for property valuation.

4. Shape

Shape refers to the shape of the parcel whether regular shape or irregular shape, it does not affect the value of the land and property directly whereas, it affects improvement and design that can be put up in that parcel.

5. Type

The type refers whether the parcel or land is built or unbuilt. However, this goes hand in hand with land use and development condition that can be filled by specifying the number of buildings required, construction coverage ratio and allowed a number of floors in an individual parcel.

b. External factors - Location factors

As shown on Figure 2-1 in this thesis, location factors such as neighbourhood, accessibility (roads) of the property, public facilities, utilities and infrastructures, affects property value. As general findings on the locational factors, the respondents highlighted that "*locational factors are essential elements that need to be examined and affect property value one way or another*". Therefore a property "*located in Central Business District (CBD) is more worth than a property located in the peri-urban area even if the size, materials and utilities are the same"* said by the focus group discussion participants.

1. Neighbourhoods

The neighbourhood is a crucial factor in the specific surroundings that affect the value of the property. The surrounding features of the property are determined by the buffer around that property in a particular area. Throughout fieldwork, the participants from focus groups discussion underscored that "l*ocation is the most important factor to be considered compared to the physical factors*". During the focus group discussion, the participant ranked neighbourhood factor as the first factor influencing the property value in a specific area. The levels of surrounding development to the property affect its value. These developments include transport facilities, retail outlets, service outlets and public facilities such as schools, markets, health centres, parks, churches, hospitals, manufacturers among others. For instance, a property that stands out as being too different from the others will also differ in price even being in the same neighbourhood.

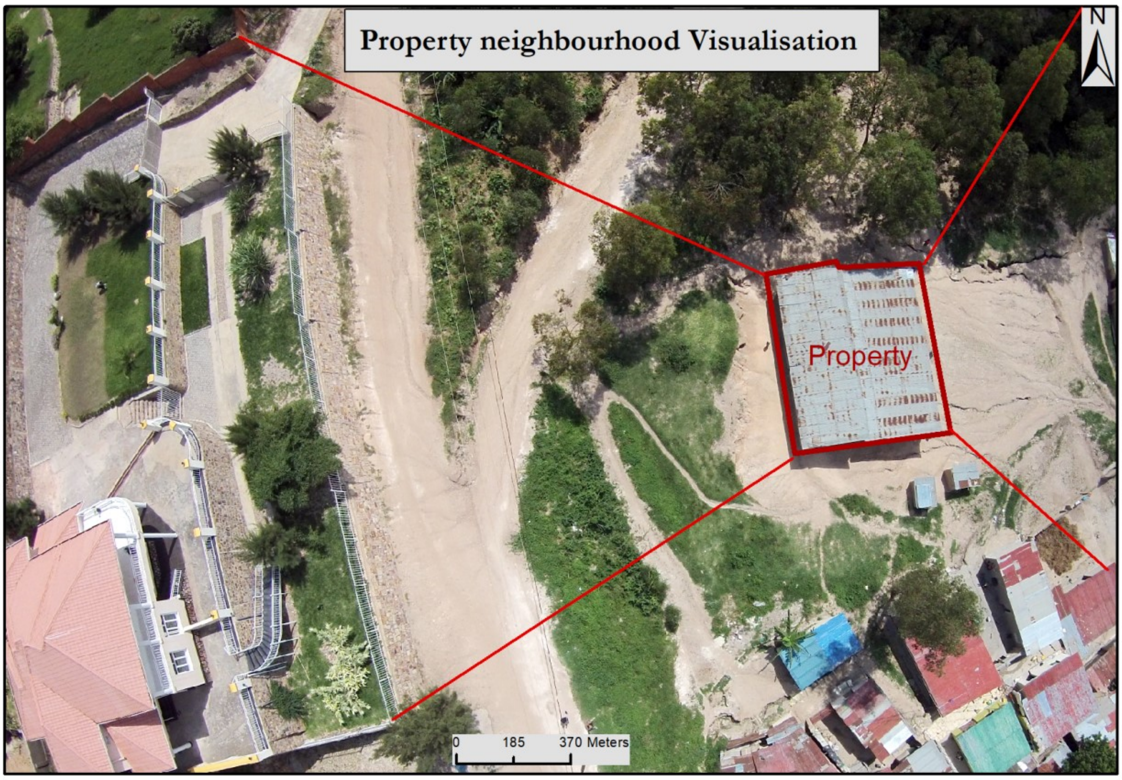

Figure 4-12: Neighbourhood visualization of the property

2. Accessibility

Accessibility is measured by the level of how the property is accessible. During the discussion with valuers, they highlighted that *accessibility is more related to the road infrastructures and defines whether the property is accessible by primary roads or districts roads, water pipes, fibre optic or internet and electricity.* For instance, if the property is directly attached to the tarmac roads is more costly than the property located on the marram road in the same area. Accessibility was ranked as the third factor influencing the value of a specific property after neighbourhoods and construction materials. For example, sampled property 3 & 4 as shown on Figure 4-13 both have access to the marram roads.

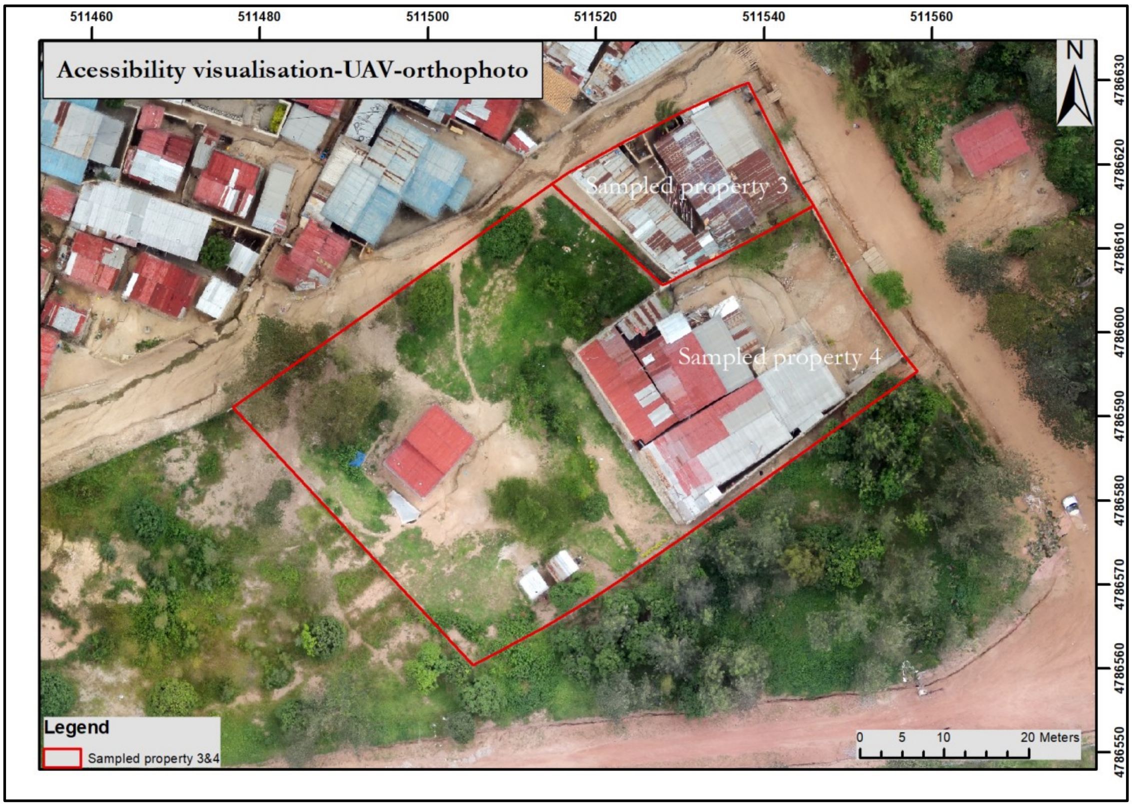

Figure 4-13: Accessibility visualisation of sampled property 3&4 from UAV-orthophoto

3. Land use/Zoning

Land use can be either current use of the land or intended use as specified by the master plan. In Rwanda, the land use master plan for the entire country was developed in 2011. District development plan was developed by referring to the developed National land use masterplan. Property valuation considers the highest best use of the land as is being used and intended or planned to be used depending on the surrounding developments in that areas. Results from the focus group discussion with valuers in Rwanda underlined that "*highest and best use of the land is tangibly potential, officially permitted, most economically feasible, and outstandingly profitable*". For valuation purposes, it is important to examine and put into consideration the issues of zoning and its changes. Also, land use planning laws need to be considered. For example, the development project must fulfil the requirements of intended land use of the area by constructing the proposed structures on the specific parcel. Throughout the discussion with valuers thought that "*Masterplan of all districts should be online and open to the public as the Kigali master plan 2013 is mostly friendly and it is used as a method of land use checking and location of the subject property*". Figure 4-14, shows the planned land use of the sampled property number 1(one of the sampled surveyed properties in Table 3-2). All allowed and not allowed constructions are specified in the zoning guidelines, and it can be downloaded from the online master plan. The current master plan was developed based on the orthophoto from aerial images 2008, and this is being used in property valuation profession due to the fact that valuers use it as a trustable source of information.

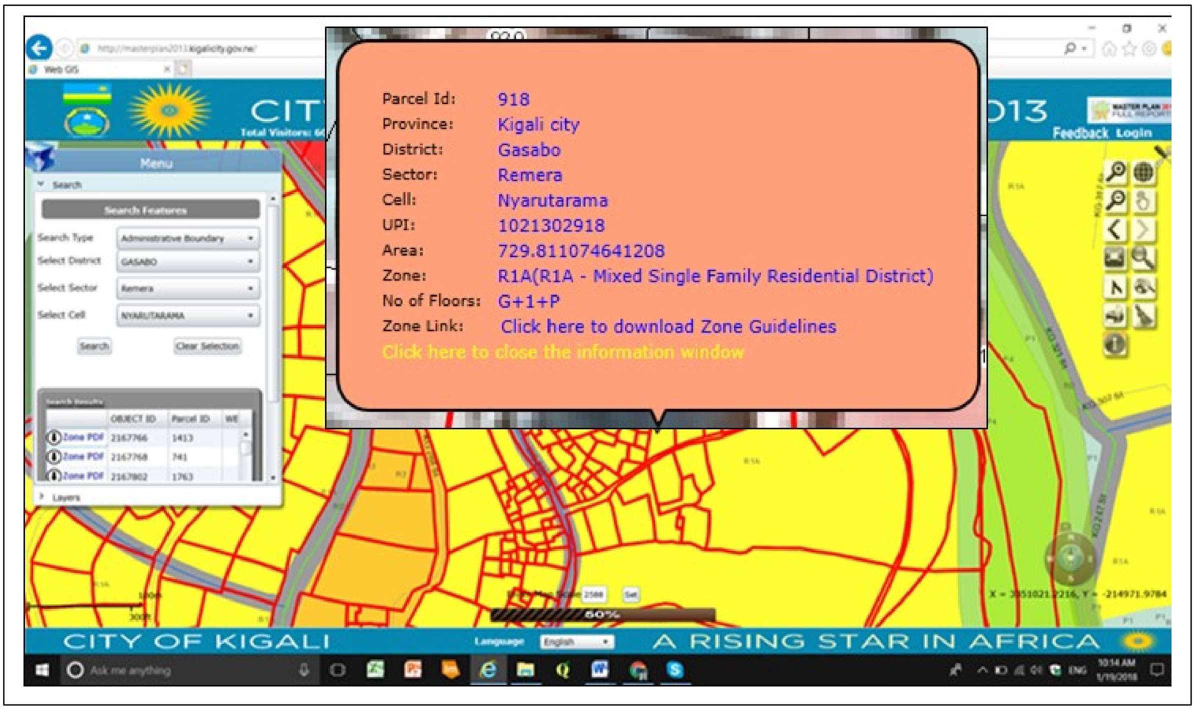

Figure 4-14: Planned land use of sampled property four via Kigali masterplan 2013

(Source: http://www.masterplan2013.kigalicity.gov.rw/)

4. **Environments**

The environment in this research refers to geographical condition a specific area where the property is located. Interviewee shared that "*the area disposed to the effects of natural phenomena, such as flooding, high winds, earthquakes among others, are poor choices when buying property*". The property located near the wetlands, informal settlement areas and other prone area are worth less than the area located in an approachable environment. Remote sensing data can be useful to analyse and visualise the prone area compared to the location of the property.

5. **Utilities**

The utilities in this research refer to the services or features that are connected to the properties such as water pipe, electricity, gas, sewage drainage and other facilities. With remote sensing data, utility features can be distinguished from other features. Especially UAV- orthophoto more accurate and precise information on the ground can be extracted compared to the satellite and orthophoto from aerial images.

4.3. Evaluation of developed UAV-based method for data collection for property valuation

Evaluation of a developed method for data collection for property valuation using UAV was done during fieldwork through the interview and focus group discussion. Evaluation of the developed approach was done to answer the sub-objective 3 of this research. The elements of evaluation of the developed method for property valuation was established based on the fit-for-purpose elements as identified by Stig Enemark, el. (2014), such as reliable, flexible, participatory, upgradeable, attainable and affordable. These elements were adjusted and grouped into elements of evaluation in this research as such *Accuracy, Completeness, Up-to-datedness, Cost and Availability of platform*. Developed criteria/elements of evaluation and their results for new developed methods using remote sensing data are discussed as follows:

4.3.1. Accuracy evaluation

Evaluation of accuracy in this research was done based on the comparison of the spatial accuracy, temporal resolution, radiometric resolution and spectral resolution as shown in Table 3-4. The results show that from orthophoto based on UAVs images with 3.3 cm accuracy the precision of digitization is much higher than the one from satellite and aerial images. Also, the evaluation of accuracy was also done through comparison of property area. Therefore generated areas from manual digitization from the UAV-orthophoto, existing dataset based on the orthophoto generated from aerial images (LAIS database) and satellite were compared with the measured area of the same properties using GNSS as shown in Table 4-5, 4-6, 4-7.

Table 4-5: Area comparison between Existing database (based on the aerial orthophoto) and Measured (GNSS)

Sampled property	Parcel area in m2		
	LAIS-Database	**Measured with GNSS**	**Difference**
Property 1	729.81	710.72	-19.09
Property 2	488.95	556.57	67.62
Property 3	476.66	375.8	-100.86
Property 4	2295.25	2473.12	177.87

Table 4-6: Area comparison between Digitized from UAV-Orthophoto and Measured with GNSS

Sampled property	Parcel area in m^2		
	Measured with GNSS	**Digitized from UAV images**	**Difference**
Property 1	710.81	708.09	2.72
Property 2	556.57	554.76	1.81
Property 3	375.8	398.71	-22.91
Property 4	2473.12	2471.06	2.06

Table 4-7: Area comparison between Digitized from Orthophoto_ satellite_ Worldview 2 and Measured (GNSS)

Sampled property	Parcel area in m2		
	Measured with GNSS	**Digitized from Satellite images**	**Difference**
Property 1	710.72	764.86	-54.05
Property 2	556.57	654.23	-97.66
Property 3	375.8	383.3	-7.5
Property 4	2473.12	-	-

The three tables above show the area comparison between measured on the field of sampled four properties and manually digitized from different remote sensing data (used dataset as indicated in Table 3-4). As shown in Table 4-7, the digitized area of sampled property 4 was not provided; the main reason was that the general boundary was not visible from satellite images. As shown in Table 4-5, the huge difference in parcel area between measured from the field and existing in the database are noted followed by those manually digitized from Satellite-worldview2. The digitized area of sampled properties from UAV-orthophoto is more close to the ground truth (accurate) compared to those from manually digitized from satellite and existing parcel area digitized from orthophoto-2008.

Table 4-8: Coordinates comparison (Measured and Existing) sampled property 1

Property 1_Points	LAIS-Database (m)		Measured with GNSS (m)		Differences	
	x	y	x	y	dx^2	dy^2
1	511362.222	4786593.102	511364.887	4786591.048	7.102	4.218916
2	511373.801	4786591.718	511375.029	4786590.289	1.508	2.0426126
3	511374.818	4786569.019	511374.689	4786565.163	0.017	14.868736
4	511346.958	4786554.443	511348.044	4786554.809	1.180	0.133956
5	511353.628	4786595.369	511355.827	4786593.829	4.835	2.3716
	Total				**2.928**	**4.7271641**
			RMSE	**2.767 m**		

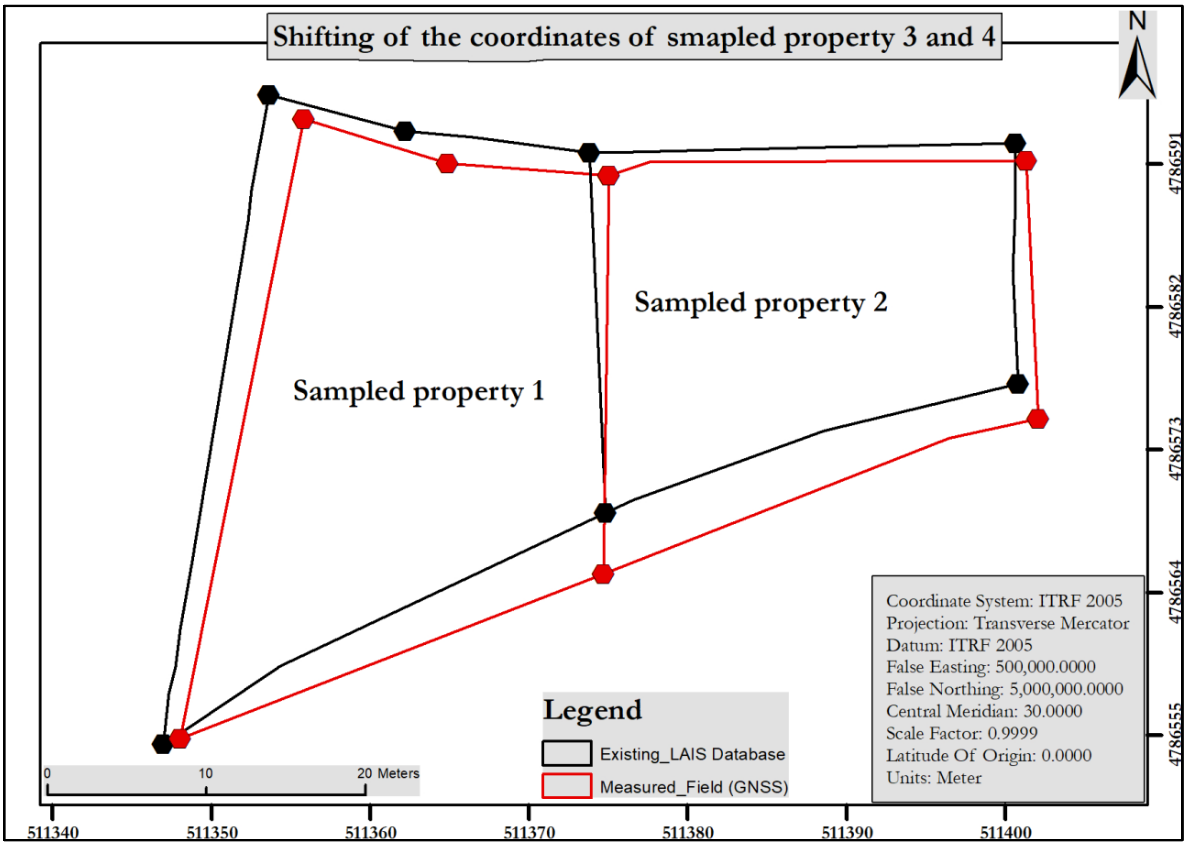

Figure 4-15: Boundary comparison (Measured and Existing) and coordinates shift of sampled property 1 &2

Table 4-9: Coordinates comparison (Measured and Existing) sampled property 2

Property2_Points	LAIS-Database		Measured with GNSS		Differences	
	X	Y	X	Y	(dx)2	(dy)2
1	511374.818	4786569.019	511374.689	4786565.163	0.017	14.868736
2	511373.801	4786591.718	511375.029	4786590.289	1.508	2.042041
3	511400.689	4786592.314	511401.326	4786591.227	0.406	1.181569
4	511400.850	4786577.176	511402.12	4786574.961	1.613	4.906225
	Total				**0.709**	**4.5997142**
				RMSE	**2.304 m**	

Table 4-10: Coordinates comparison (Measured and Existing) sampled property 3

Property3_Points	LAIS-Database		Measured with GNSS		Differences	
	X	Y	X	Y	(DX)2	(DY)2
1	511549.082	4786616.414	511546.457	4786615.077	6.891	1.787569
2	511527.852	4786605.141	511529.343	4786606.365	2.223	1.498176
3	511513.887	4786617.203	511517.161	4786618.199	10.719	0.992016
4	511539.181	4786630.565	511538.308	4786631.351	0.762	0.617796
	Total				4.119	0.9791114
				RMSE	**2.258 m**	

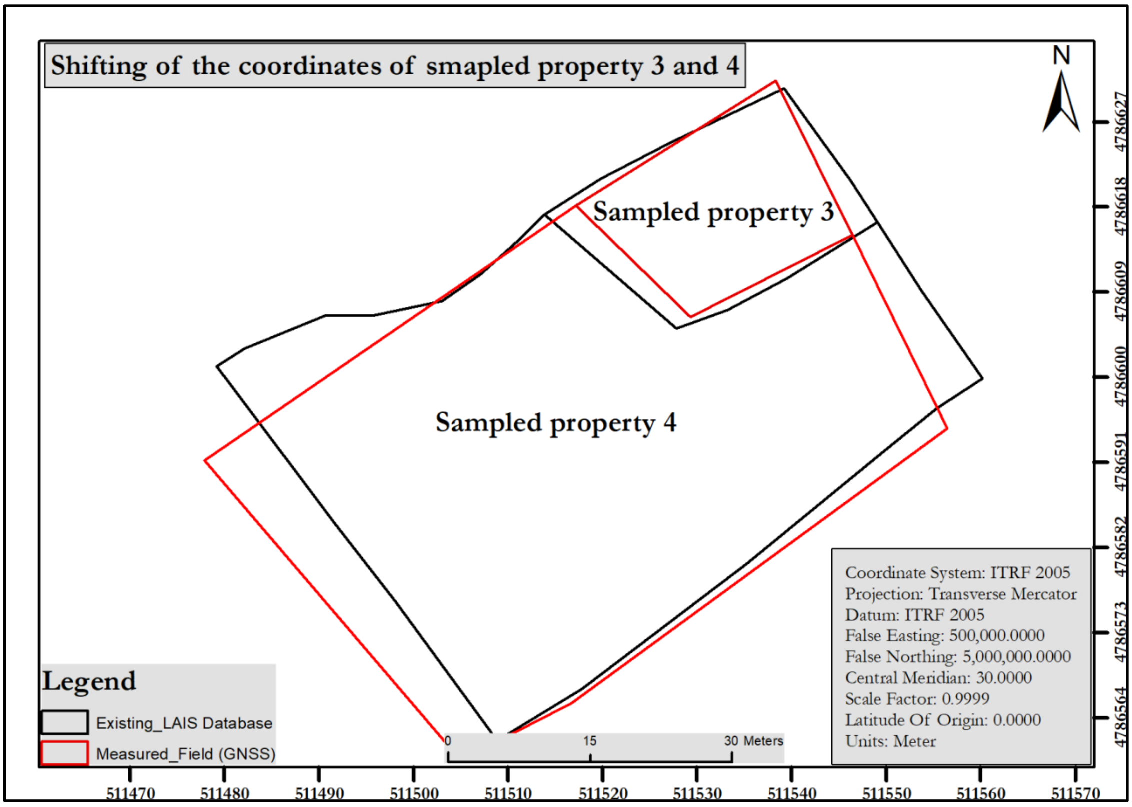

Figure 4-16: Boundary comparison of measured (red colour) and existing in LAIS (black colour) of sampled properties 3 and 4

As it can be seen in Figure 4-16 above, the shape of the parcel of sampled property four as it is (currently) in LAIS database compared to the ground truth (measured) is not the same. As a result, there is a big difference in parcel area (Table 4-6) and RMSE (Table 4-11).

Table 4-11: Coordinates comparison (Measured and Existing) sampled parcel 4

	LAIS-Database (m)		**Measured with GNSS (m)**		**Differences**	
Property4_Points	X	Y	X	Y	(DX)2	(DY)2
1	511508.802	4786561.484	511504.976	4786559.497	14.638	3.948169
2	511479.181	4786601.14	511477.855	4786591.229	1.758	98.227921
3	511513.887	4786617.203	511517.161	4786618.199	10.719	0.992016
4	511527.852	4786605.141	511529.343	4786606.365	2.223	1.498176
5	511549.082	4786616.414	511546.457	4786615.077	6.891	1.787569
6	511560.234	4786599.842	511556.489	4786594.604	14.025	27.436644
7	511517.797	4786567.041	511516.716	4786565.494	1.169	2.393209
	Total				**5.868**	**20.9332564**
				RMSE	**5.177 m**	

The shifting of the coordinates as in implication on the parcel area as it can be seen in Figure 4-16. The shape of the sampled property 4 has changed compared between what is in LAIS and on the ground, the factors that the shape is not same resulted in very high RMSE of coordinates shifting (Table 4-11).

As shown in Table 3-4, the orthophoto generated from aerial images taken by UAVs has 3.3 cm of accuracy compared to the orthophoto generated from aerial images 2008 which have 22 cm and of the orthophoto generated from Satellite Worldview2 with 50cm. During the interview and focus group discussions most of the respondents especially valuers highlighted that "*UAVs will be more beneficial for valuation as valuation need updated information and detailed information on the ground*". While only one respondent underlined that "*the issues of accuracy are not a big issue as long as they want to cover large areas, then satellite will help with property taxes*".

4.3.2. Evaluation of completeness of the data extracted from UAV orthophoto

Evaluation of completeness was evaluated based on the answers from both semi-structured interviews and focus group discussion with IRPV officials, valuers, RRA officials. In addition, completeness evaluation was based on the features extracted from UAV-orthophoto compared with required data for property valuation. Findings from focus group discussion revealed that "*the interior part of the property cannot be captured using remote sensing data, construction materials can be obtained in ascertained condition".* When the property is plastered, construction materials are not easily obtained either using physical inspection or using remote sensing techniques. Regarding the completeness of data shared from RLMUA, interviewee and focus group discussion participants highlighted that "*information provided for property tax (Fixed asset tax) is not enough (incomplete)".* During fieldwork, the interviewee from RLMUA said that *"the information related to the building, improvements within the compound of the parcel are not recorded in LAIS database*". The missing information in the database resulted in the incompleteness of the data required for property valuation for taxation purposes. Remote sensing data can be used to subsidise the existing data and make it complete. The evaluation of completeness of data that can be extracted from generated UAV orthophoto and acquired raw images is almost complete except the interior measurement of the building.

4.3.3. Up-to-dateness

The degree to which remote sensing data give updated information was established using literature review, interviews and focus group discussion data from RLMUA, IRPV, RRA, districts and valuers. Vis-à-vis updating spatial information, officials from RLMUA highlight that Rwanda land cadastre was built based on high-resolution orthophoto captured in 2008 by aircraft. An update of the existing cadastre spatial data was planned for urban and rural areas. Findings from interview revealed that "so far no updates have been done using remote sensing data as it was planned to do another aerial photography campaign". It was planned to update the existing spatial data in five years for urban areas and ten years for rural. Currently, satellite images from Google Earth are being used to complete and update the outdated orthophotos" as said by the interviewee. Updating is also done through a sporadic system whereby "field visits are required. Physical inspection afterwards of the property is done for updating" highlighted by the interviewee. Currently, updating of the spatial information is done based on the request of the landowner or government acquired land for public infrastructures. Regarding updating the data related to property valuation for taxation, valuers highlighted that "existing orthophoto provided by RLMUA is outdated. Therefore, the updated information is required as property taxes value is collected based on the open market value of land, buildings and improvements". Therefore, as development is a concern especially in an urban area where many changes have occurred on the field, and no update is being done a physical inspection is required mentioned by valuers. Valuers said that RLMUA as an institution in charges of the spatial information related to land management and use should find the approach for updating spatial information so that the data from database reflects the reality on the ground.

Vis-à-vis the property taxation is a concern, the results from an interviews with RRA and districts officials concluded that "classical approach of property to property, self-declaration from landholder are being used for updating their data". This traditional approach is time-consuming and costly as shared by the interviewee that "remote sensing techniques can be more useful tools to monitor and keep up-to-date the spatial information regarding the changes on the ground and can save the time compared to the traditional methods".

4.3.4. Cost assessment

The cost assessment is based on the previous research done in Rwanda and abroad on the usability of UAVs compared to the valuation fees in Rwanda. IRPV (2011) has set valuation fees by classifying the properties in different categories. The categories are set-up by considering the factors including type (land or building); use (residential, commercial and industrial); and location context (urban, peri-urban and rural area). The detailed cost breakdown of the current property valuation fees and developed UAV-based method are shown in Figure 4-17.

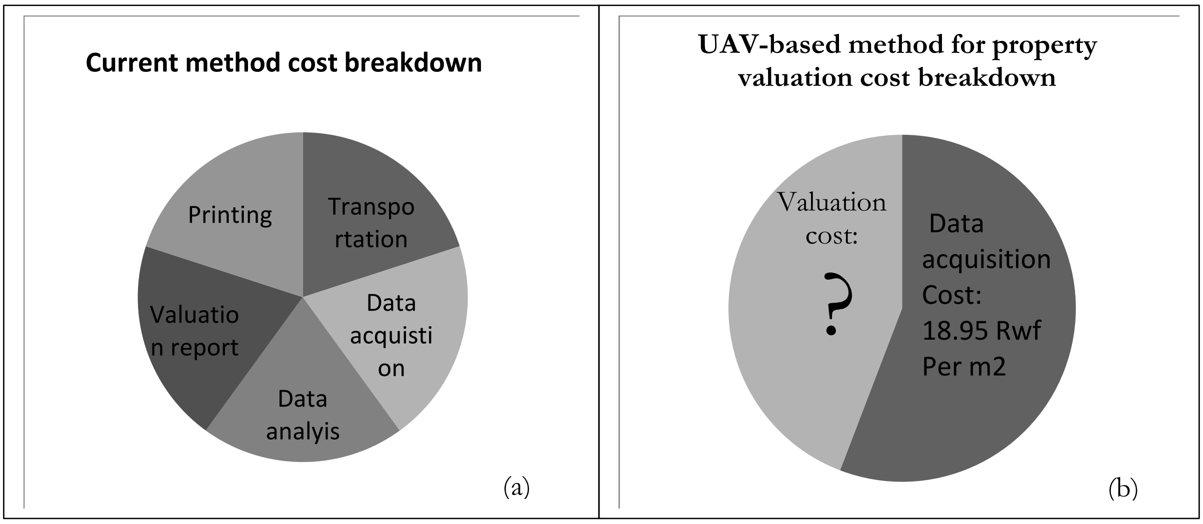

Figure 4-17: Cost assessment of the current property valuation method (a) and developed UAV-based method (b)

As shown in the Figure 4-17, the cost breakdown of the current valuation fees includes transport fees, data collection, data analysis, valuation report preparation and printing. According to IRPV, (2011) valuation fees guideline, the average cost of the charges for property valuation in an urban area is around 1050 Rwf per square meter. However, the document does not specify the cost of each activity as shown in Figure 4-17 (a). For the UAV-based method, the cost was shared by the Charis Company; the only registered and allowed to fly in Rwandan territory. This cost is involved the following activities permission, pre-planning, operator, data acquisition and post-processing. As shared the estimated cost is

$1100 per five hectares which equivalent to 18.95 Rwf per square meter. The cost was converted into Rwf francs for better comparison. The online exchange was used as exchange rate at the time was 861.42 Rwf /dollar. The cost comparison of the two methods was not completed due to valuation fees charges are not well break-down for better comparison as shown in Figure 4-17 (b).

4.3.5. Availability of the platform

During the interview discussion with an official from Ministry of Infrastructure shared that "only one company is registered and has the right to fly UAVs". The availability of platform is the main key to cutting off the cost of hiring an external company to perform the photogrammetric process. According to the news of 15/11/2017 on harmonising the regulations of using UAVs in Rwanda reported by igihe.com highlighted that *"currently in Eastern and South Africa's countries around six thousand UAVs are available and being used in the different sectors"* as announced by Barry Kashambo (director of ICAO in South and East Africa). For instance, UAVs are being used in *surveying*, *transportation among others*. Also, in this news, Minister in charge of transport in Rwanda pointed out that "*there are a lot of applications pertaining using UVs in Rwanda that is why the regulations should be harmonised"*. Aerial imagery can be acquired using conventional platforms such as satellites and aircraft; however, their temporal resolution is limited by availability orbit characteristics of satellites and aircrafts platform (Turner, Lucieer, et al., 2012). The unavailability of these platforms and orbits limit their use in this case as it will increase costs and the production time.

4.3.6. Advantages and disadvantages of the developed UAV-based method for data collection for property valuation in Rwanda

Table 4-12: Advantages and disadvantages of the developed method for data collection for property valuation

Advantages	Disadvantages
- Developed approach can produce highly spatial accurate data for property valuation compared to the current approach - Existence of the regulation on use of unmanned civil aircraft system in Rwanda - There are still high number of company applications for registration for using UAVs - Availability of the infrastructure and platforms in Rwandan territory - Developed approach can be used or fly almost everywhere - Developed method can be used to update the outdated spatial information - Almost all required data for property valuation can be obtained using the developed method	- Lack of human resources with adequate skills to run the developed methods - Only one company has registered to perform aerial survey using the developed method up to now - Lack of funds to train the users to use the developed methods - Developed method is not efficient for only one property - Developed method cannot capture the interior part of the property - Developed approach requires high specification of Geo-ICT support

Conclusion remarks

This chapter represents results of collected data from semi-structured interview respondents and focuses group discussion participants (the interviewees and participants included government officials and private valuers). The findings were presented according to the objectives of this study. The current property tax system in Rwanda is based on the area based and open market value. Three types of taxes related to property tax were described such as lease fee, rental income tax and fixed asset tax. Thus the last one requires valuation report. The open market values include the value of land, buildings and improvements within the parcel compound. The current methods used to collect data for property valuation for taxation were presented. The issues of lack of data, outdated of spatial information push valuers to physically inspect the property to collect the required data. Table 4-1, shows the required data and the possible sources of the information (where current being collected). The usability of remote sensing data in

Rwanda has been used since 2008, and currently, no update is being done. The challenges of not having enough funds and trained staff to use remote sensing techniques are limited, and the usability of remote sensing data into property valuation for taxation purposes is less used.

Different remote sensing techniques were discussed such satellite, aerial, UAVs and terrestrial. However, for some of these platforms, the availability is problematic such as satellite images and very costly like using aerial images taken from aircraft. From the interviews and focus group discussion with officials on the usability of these different remote sensing techniques, it was concluded that UAVs are more suitable for property valuation. Images captured by UAVs have higher spatial resolution compared to the conventional platforms such as satellite and aircraft even with less area coverage. As property valuation requires detailed information, the issue of resolution and accuracy is very important. The results of parcel area comparison also show that the area manually digitized from orthophoto from aerial images, satellite and UAV-orthophoto with measured with GNSS (reality) on the ground. UAVs data is closest to the reality compared to the others. Based on reviewed literature and suggestion from respondents the new approach for data collection for property valuation using UAV was developed as shown in Figure 4-6. Elements of comparison were developed and evaluated based on their accuracy, completeness, up-to-dateness, cost and availability of platform. Factors affecting the property, the completeness and up-to-datedness of required data were verified using the new developed method. Regarding the completeness of the data, the inner part of the buildings cannot be captured using a new developed method. However, other methods can be applied in contribution to UAVs one.

5. DISCUSSIONS

In chapter 4, the results from the collected data from interviews, focus group discussion and geodetic surveying and observation based on the remote sensing data are presented. The information on the current property valuation for taxation system and usability of remote sensing data were collected from the government officials (central and local) and private valuers. This chapter discusses the results presented in the previous chapter in line with the three sub-objectives of this research according to the usability and comparison elements with the different remote sensing data. The elements of comparison were identified in the reviewed literature and examined from the interviews and the focus group discussion.

5.1. Current situation of property valuation for taxation system in Rwanda

Regarding the current status of property valuation for taxation in Rwanda, property valuation profession is regulated by concrete laws and regulations. It is governed by the real property valuation law (GoR, 2010) as described in section 4.1.1 of this thesis. The law focuses more on the establishment of Institute of Real Property Valuers (IRPV) in Rwanda, its functions, organizations and responsibilities. The law also establishes the regulatory councils and its responsibilities. In section 2.1.1, the currently used property valuation methods are discussed. However, the use of other methods is allowed upon approval by the Regulatory Council. It states that "the valuer may use any other relevant worldwide methods not provided in the real property valuation law in order to carry out the assigned work" (GoR, 2010; Thierry, 2014) in the law above. Since the big part of this law is administrative, the brief legal analysis focuses on the valuation methods. As reported in results section 4.1, the law does not address the methods and tools that can be used to collect the required data. The results indicate that the harmonisation of property valuation profession in Rwanda is needed. The valuers should have the guidance or property valuation standard showing which methods, tools to be used to collect required data in this profession. Although some of the valuers said that there is valuation standard, based on the provided document and reports, there is not the existence of such in Rwanda (Ministry of Natural Resources, 2014).

Concerning property tax (fixed asset tax), the taxation system has been developed, but it is still hosted at the national level. According to the law establishing the sources of revenue and property of decentralized entities and governing their management, the property tax should be collected by the districts (GoR, 2011). Districts have not invested in establishing appropriate revenue collection systems. These resulted in contracting the Rwanda Revenue Authority as system holder to collect the tax on behalf of the districts. Currently, self- declaration and ad-hoc systems are being used in Rwanda as the taxation system. Richard and Slack, (2002) reviewed that self-assessment requires property holder to set the value of its property on their property. In Rwanda, it is the responsibility of the taxpayer to assess their properties and come up with the property value to fill the declaration form. Therefore, in Rwanda, the taxpayers are obliged to register and report their tax obligations to the tax collector (Uwihoreye, 2016). A challenge to the current system is that not all taxpayers comply with this system of self-declaration (self-registration). With the self-assessment system, taxpayers are likely to undervalue their property as the tax is based on the open market value and the fixed rate is applied.

With regard to determining the open market value of the property, it was noticed that valuers use the methods previously described in section 2.2.1 to analyse the collected data and value the property subject to property tax. Because of lack of required data to estimate the open market value of the taxable property, replacement cost approach is more used compared to other methods. The issue of lack of data on market transactions resulted on using different sources of data and the effectiveness of the declaration re-assessment (Uwihoreye, 2016). Regarding the completeness of the provided data from RLMUA, the records of the transactions as the basis of market value assessment are not well recorded. One respondent from RLMUA indicated that the value of land, buildings and improvements are not separated, instead is recorded as a land value in LAIS database.

Regarding the required data for property valuation for taxation purposes (as described in section 4.1.3.) currently most of the information is collected from fieldwork. Section 2.2.2 showed that the required data are classified in both physical and locational factors, but also other categories such as legal and economic factors should be considered. Respondents highlighted that the most required data to value the property includes land certificate with built-up area, technical conditions, construction materials land use and infrastructure attached to it. The land certificate shows ownership of the property, current land use, tenure type, location of the property (from districts to the village) and parcel size. Only this information described above exist in LAIS database and is available to be used in property tax. The remaining data requires field inspection to collect the missing information to fill the gaps of required data and existing one. The incompleteness and outdated of spatial information of land cadastre in Rwanda were noticed and reported by others researchers such as Uwihoreye, 2016; Biraro, 2014 and Muneza, 2015). The issue of lack of funds resulted does not update the spatial information as it was planned. Currently used methods for data collection, each valuer has to find out the way the data will be available to execute their duties. There is no any guidance document or rules being followed by valuers on how data can be collected and which tools can be used.

Therefore, remote sensing data can be used to address this problem of the incompleteness of the data and can be used as a source of data for property valuation for taxation. As it is shown in Table 2-1, it has been proven that required data can be retrieved from remote sensing data. Freeman, (2017) discusses that only interior part of the property cannot be adequately ascertained using UAV-derived products. Vis-à-vis to the up-to-dateness of the current spatial data about the property valuation, the existing data in Rwandan land cadastre is outdated.

The usability of remote sensing data in Rwanda is not new since the land cadastre was built based on the orthophoto from aerial images acquired using aircraft and satellite in 2008. As described in section 2.1.3, aerial imagery can be obtained using conventional platforms such as aircraft or helicopters nevertheless; their temporal resolution is limited by the availability of aircraft platforms, pilot licenses, flight regulations and the expertise of the specialists (Turner, Lucieer, and Watson, 2012). Due to this limitation in developing countries, they are hard to be used for the regular update of digital information. Similar findings were noted during the interviews that to update the existing spatial data another flight campaign was planned and prepared, thus funds are still needed. Nevertheless, satellite images from Google Earth are used as additional source of information to update the outdated information, especially for property valuation, while for cadastre it is not enough and requires field survey. Since nine years ago, there is no update being done using remote sensing data. There are a lot of changes happing on the ground for spatial and non- spatial information. It has noticed that usability of remote sensing data in property valuation for taxation is very low as traditional methods play huge importance, especially in data collection. As reviewed in ministerial regulations N^0 01/MOS/Trans/016 relating to unmanned civil aircraft the usability of remote aircraft is allowed, and it provides the procedures of how the permit should be issued (GoR, 2016).

5.2. Developed UAV-based method-for data collection for property valuation for taxation in Rwanda

The developed UAV-based approach utilized UAV images and orthophoto to extract physical attributes such as parcel area, built-up area, improvements and constructions materials. The developed UAV-based method was developed to respond to the issues of the traditionally used approach (expensive, time-consuming and inaccurate). It is shown that UAVs can provide very high spatial and temporal resolution data at low cost compared to the conventional aerial photogrammetry or satellite-based method (Koeva et al., 2016 and Ramadhani, 2016. Regarding the current traditional methods used for collecting data for property valuation, the respondents highlighted that its time consuming and costly. The fact that Rwanda also has a challenging landscape with often hilly terrain also creates problems during field inspection for data collection. It is proven the measurement of the property and improvements are often measured used in the field using tape measure can be done in the office using the generated orthophoto (Table 4-3) thus reducing field inspection and time used to measure.

Throughout this developed UAV-based method, the required data for property valuation for taxation purpose can be achieved. With high-resolution images and orthophoto produced from UAV, the updated information seems applied and achievable. It has been proven that the cost to use of unpiloted aircraft survey is 30% of the cost of the survey using terrestrial survey (Ramadhani, 2016). It is seen that remote sensing data can be a reliable source of information which can be very beneficial for property valuation. The comparative elements were developed based on the factors affecting the property value as described in Figure 2-1 and tested from the developed UAV-based method.

5.3. Evaluation of developed UAV-based method for data collection for property valuation for taxation

Throughout an evaluation of a developed UAV-based method for data collection for property valuation, the element of the evaluation was developed based on the fit-for-purpose elements.

Regarding the accuracy of the developed approach, the generated output orthophoto from UAV approach is more accurate compared to satellite images and orthophoto from aerial images. As shown in Table 3-4, the generated orthophoto from UAV has higher spatial resolution compared to the satellite and aerial orthophoto of 2008. Therefore, more details can be obtained on the ground. Tables 4-5, 4-6 and 4-7, show the comparison between actual area (measured with GNSS) and area digitized from different remote sensing data (Table 3-4). *The results prove that the area digitized from UAV- orthophoto is closest to the ground truth* as is indicated in Table 4-5. The shifting of the coordinates has the impact on the parcel area and also the shape of the property. As described in Table 4-8 up to 4-11 the Root Mean Square Error (RMSE) of shifted in coordinates are related to their difference, especially in the parcel area. For example, the sampled property 4 has RMSE of 5.177m, and their difference in area is big as seen in Table 4-5. Relating RMSE to parcel area; it has noticed that the higher RMSE (Table 4-11), the higher differences in parcel area (Table 4-5). Even the area that is captured by UAVs is smaller than satellite, aerial they are more suitable for the details that are needed to be recorded for property valuation for taxation purposes.

Regarding the completeness of the data extracted from UAV-orthophoto, the developed UAV-based approach gives an overview of aerial understanding of the particular area, thus permitting the documentation of characteristics of the property and its improvements. It was noted that the only information that cannot be captured using developed UAV-based method regards to the interior party of the buildings. However, for the interior part measurement, the data from construction permitting office can be used to complement the new developed approach. The interior measurement and accommodation can be obtained from the construction structure plan.

Regarding up-to-datedness of the data, the UAVs acquired images and generated orthophoto give a detailed, up-to-date illustration of the interested area and its improvements. Based on its temporal resolution, spatial accuracy and its flexibility of being used anytime at any location, after the fly, the provided or generated data from UAVs are detailed and up-to-date. As property valuation requires the accurate and updated information, the update is very essential, and it has been proven that UAVs can be used to update the spatial information (Koeva et al., 2016). The developed UAV-based approach can be used to visualise changes from the field through changes detection by using the data capture in the same area in a different period.

Regarding the availability of the platforms, once the platforms are owned locally the cost of ordering locally or hiring an external company will be cut off from the expenses. Also, if the platform is available, the time can be used efficiently as hiring foreign companies can also be time-consuming. Lastly, the availability of the platform is an important element for motivation for data collection and timely update of the data.

Conclusion remarks

The results presented in chapter 4 were discussed in this chapter. The results from each sub-objective were discussed and related to the literature and other findings from previous studies. There were no unexpected findings different to the previously the anticipated results. The results and discussion of the first sub-objective are more related to the current situation of the property tax system, the laws and regulations. The developed UAV-based method was evaluated based on the developed elements and the linkage between the findings and the literature.

6. CONCLUSION AND RECOMMENDATION

This research set out to assess and compare the usability of different remote sensing data for property valuation for taxation purposes in Rwanda. In the previous chapters, comparisons of the used dataset in this research were made. Findings from literature, interview and focus group discussion show that UAVs dataset is more suitable for property valuation than satellite and aerial images taken from aircraft. In preceding chapters, the method for data collection for property valuation using UAVs was developed and evaluated regarding accuracy, completeness, up-to-dateness cost and availability of platforms. The advantages and disadvantages of developed method for property valuation for taxation purpose were discussed. This research was attained through three stages including pre-fieldwork, fieldwork and post-fieldwork. Pre-fieldwork consisted of preparation for data collection, and it involved the comparison of the used datasets in this research. The results from the comparison were verified during the fieldwork and collected data processed and analysed after fieldwork. Based on the results, conclusions and recommendations of this research are discussed and presented in this chapter.

The main outcomes achieved in this research indicate that UAVs data is most suitable compared to satellite images and aerial images taken from aircraft. The developed method based on UAVs data for property valuation for taxation was developed and evaluated in terms accuracy, completeness, up-to-dateness and availability of platforms. Based on the findings and expectations from RLMUA, RRA and valuers, UAVs was found to be most beneficial for both updating the spatial information and for collecting data for property valuation for taxation purposes. Findings of the research revealed that this technology is being used in others sectors in Rwanda especially in transportation and can be used in other activities including property valuation. Regarding property taxation, the respondents noticed that UAV also can be used to monitor and update the taxable property information and can save the time compared to the classical method of the house to house.

6.1. Conclusion

Sub-Objective 1: To review the current property valuation for taxation system in Rwanda

It was found that property tax in Rwanda is regulated by the government, through the Rwandan Revenue Authority (RRA) and involves different actors. The property tax (fixed asset tax) is based on the open market value and requires the opinion of the competent valuer. The results also reveal that property tax does not have its specific law, but it is governed by the law N^{o} 59/2011 establishing the source of income of decentralised entities. The current spatial data from RLMUA is outdated, and their accuracy is too low, UAVs can be used to update and acquire data where missing data for property valuation for taxation purposes is needed. The acquisition of required data for property valuation for taxation is still undertaken with terrestrial method (physical inspection) using tape measurements, handheld GPS, digital cameras among others. Results revealed that remote sensing data especially UAV could be more beneficial to this professional of valuation in Rwanda thus, the availability of regulations and platforms in place it can be an advantage for it.

It has been noticed that remote sensing has been used in Rwanda for the land issue since 2008, but there is no update done yet. Some of the challenges of updating the spatial data in Rwanda include lack of finance, trained staff in this profession and also only one company is registered to perform this task, but its capacity is limited. Regarding the use of remote sensing in Rwanda, review of regulations regarding

Civil Aviation in Rwanda, especially its annexe on usability and registration of "unmanned aircraft system" was done. Findings from existing regulation in Rwanda revealed that UAVs could be only flown after registration and flight permission delivered from the Rwanda Civil Aviation Authority (RCAA).

Sub-Objective 2: To develop a new approach for data collection for property valuation for taxation in Rwanda using Remote sensing data.

It was revealed in comparison; the results revealed that UAVs is more accurate, fast and cheap compared to other remote sensing data. The UAV-based method for property valuation for taxation purpose was developed through adapting general workflow of orthophoto generation and tested to respond research question 2.1. and 2.2. The developed approach comprises of four main stages which include data acquisition, data processing, output generation and use of the output in property valuation for taxation purposes. It has noticed that the generated orthophotos and raw acquired images serve as sources of required data for property valuation. Findings revealed that except the interior party of the property other required data can be captured and obtained from orthophoto and raw images from UAVs with high accuracy and on time. Compared to the classical methods for data collection and processing, the respondents and literature recalled that UAV-based approach saves time than terrestrial surveying. With the developed UAV-based approach, the details of the property can be determined and measured with high accuracy. The results revealed that the digitized parcel area, built-up area and improvements are more accurate and closer to the ground truth. The three first steps can be followed when the update of a particular area is required. In additional developed UAV-based approach can be used to monitor the changes and facilitate government of Rwanda to reduce the time used to update the taxable properties through the house to house approach.

Sub-Objective 3: To evaluate the new developed approach against the developed criteria's for property valuation for taxation purposes in Rwanda

The evaluation of the developed method using UAVs for property valuation for taxation purpose was done through adapting the fit-for purposes approach elements. The elements were grouped into four main elements which serve as evaluation criteria for the new developed method. The valuation criteria include the accuracy, up-to-dateness, completeness and availability of the platforms in Rwanda. Results showed that the required data for property valuation can be obtained through digitisation of generated orthophoto from UAV is more accurate and the features or other information is updated compared to the existing data from LAIS-database and Satellite images. Additionally, the results revealed that UAVs images and orthophoto give them a complete and up-to-date information representation of the interested property and its improvements.

Given the high spatial information that can be obtained from acquired images and generated orthophoto from UAVs, the physical attributes such as built-up area, technical condition of the property and locational factors can determine and describe. Furthermore, through the generated output the improvements on property or changes can be identified and determined. Regarding the completeness of the required data for property valuation, the interior part of the property cannot be measured from remote sensing data; however, the integration of the developed method and another source such as construction permit data will be more efficient. The results of this study revealed that only one company is registered and have the right to fly UAVs in Rwanda. However, the government have emphasized to facilitate and harmonise of using the technology especially UAVs in Rwanda. The advantages and disadvantages of the developed approach were determined based on the previous research, interview and focus group discussion.

6.2. Recommendation

The study was aimed to assess and compare the different remote sensing data namely satellite images, orthophoto from aerial images and orthophoto from UAVs for property valuation for taxation in Rwanda. Based on the developed comparative elements, the comparisons of different remote sensing data were examined. Therefore, the recommendations for this research are structured as follows:

- **Government and private institutions**

Findings from this research and others research previously done revealed that the existing spatial data are outdated and require an update. It has been concluded that property valuation requires updated spatial and non-spatial information.
The recommendations of this research to public and private institutions are:

- To use Unnamed Aerial Vehicles (UAVs) for updating the spatial information as it is more accurate, cheaper and faster compared to satellite, aerial l images. In fact that UAVs contains more detailed information even if the captured area is less compared to the others.
- To collect data and make them available and accessible to other users for public use.
- To introduce the Fiscal cadastre aspect as current land cadastre is still missing important features for property valuation for taxation such as buildings, transaction cost among others.
- To enhance capacity building of staff and users on the new technology of using UAVs as currently only one company is registered in Rwanda
- To use new technology especially UAVs to monitor and update the taxpayer's properties since it is more beneficial compared to the traditional methods
- To quickly put-upon the property valuation standard as guidance umbrella of this profession in Rwanda

- **Further research**

The foremost motivation behind adapting fit-for-purpose approach is to enable the collection of required data at minimum cost, in the shortest time while upholding the required accuracy. Therefore, there is a need for further on research on assessing the effectiveness of the developed UAV-based method compared to the existing methods for data collection for property valuation.

6.3. Reflection on the results

The results from the collected data were enough and are liable and trustable. Data were collected from different institutions and private valuers. The participants and respondents had the right to express their ideas and ask the questions for better understanding the key concepts of this research. The researcher is working in Rubavu district as director of infrastructure one-stop centre. The participants were not connected to the researcher before fieldwork. They were asked to participate as part of the group discussion and independent interviewees after the formulation of this study. Therefore, there was no influence of the researcher to the participants because there was no professional or other relation. The proof of this is the honest and different answers of the participants.

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LIST APPENDIX

1. Stakeholders involved in property tax system and their responsibilities in Rwanda

Stakeholders	Responsibilities
Taxpayer	- To declare the property or ownership - To undergo the assessment of the property if required - To pay the taxes
RRA	- To collect the taxes - To sensitise the population about fixed asset taxes - To notify the taxpayers about fixed asset taxes and land lease fees - To send bills or invoice to the taxpayers regarding taxes or land lease fees - To recover the taxes if required - Prepare the list of taxpayers and update the list
RLMUA	- To disseminate data related to spatial and non-spatial data related to land - Regulate the property rights or land tenure type by providing both lease & freehold; property tax is based on the land tenure type - To provide technical support related to spatial information - To collect and update the LAIS information
Districts	- To collect local taxes - To sensitize the population about taxes - To notify the taxpayers of taxes and deadline - Prepare the list of taxpayers and update the list - To send bills or invoice to the taxpayers - To recover the taxes if required - Decision making by district council on the land lease fees rate depending on the location and development
Valuers	- To determine the open market value of the property - To assess the value of the property to be taxable - Valuers help the citizens by preparing the valuation report, and this valuation report can be used to calculate the property tax value property
IRPV	- To regulate the valuation professional - To solve conflict if raised between valuers or valuers and clients - regulate and register the new valuers by updating the new, certified valuers and fresh train valuers
RDB	- To register caveat when the property is confiscated by the RRA
Banks	- Facilitate payment

2. Comparison assessment of the used datasets

No	Remote sensing data	Variables/ Basic remote sensing characteristics				
		Spatial(cm)	**Temporal**	**Radiometric**	**spectral**	**Type stereo**
1	Satellite Worldview 2	50	1.1day	16-bit	4 bands	Flexible
2	Orthophoto from Aerial images	22		8-bit	3 bands	Along Track
3	Orthophoto from Aerial UAV	3	Any time	8-bit	4 bands	Along Track
4	Terrestrial Images		Any time			

3. Key informants Interview Questions

This survey is part of research project entitled "**Innovative *comparative assessment of different remote sensing data for land valuation for taxation purpose*.**" The research is conducted by **Oscar Gasuku**, an MSc Student at the University of Twente in Faculty of Geo-Information Science and Earth Observation, the Netherlands. Your contribution is highly appreciated and is of that great help to the realisation of the research project objectives. I ensure you that the responses and feedback will be kept anonymous and confidential and will be solely academically used. **Please answer the following questions** as part of your involvement and participation in helping develop more understating on this research. Thank for your assistance.

<u>Interviewee Information</u>

Position…………………………………………………

Organization …………………………………………….

Years of experience in the field ……………

A. Interview guide questions with Rwanda Land Management and Use Authority officials

- ✓ How does your institution, your job help land/property valuation for taxation purpose?
- ✓ Have you been using remote sensing data such as Satellite images, images taken by aircraft, images taken by Drones (UAVs), terrestrial images for anything in your work?
- ✓ Are there any regulations regarding the use of Remote sensing data for Property valuation for taxation purposes?
- ✓ How often do you update your Remote sensing data?
- ✓ How are the updates done? Are there different remote sensing data use?
- ✓ Would you please briefly explain what the processes or steps required for updating the current valuation data/maps are?
- ✓ What are the limitations and challenges to collect data for land/property valuation currently?
- ✓ Would you suggest using remote sensing data for land/property valuation for taxation?
- ✓ Would you please estimate the cost of images processing based on the previous project?

B. Interview guide questions with officials in Real property valuers Institute

- ✓ What are the institutions involved in property valuation for taxation purpose and their role?
- ✓ Is there any valuation standard, regulation, policies to guide the property valuation professional in Rwanda?
- ✓ Which methods and steps currently are being applied for collecting data for land/property valuation for taxation?
- ✓ What are the required data for land/property valuation for taxation purposes?
- ✓ What are the current techniques do you use to collect data for property valuation for taxation purposes?
- ✓ Is there a scheme of indexation affecting property value between regular revaluations?
- ✓ Are you familiar with remote sensing data like Satellite images, Aircraft images, Drones (UAVs) images, terrestrial images?
- ✓ From the Remote sensing data we discussed above would you consider using them for land/ property valuation for taxation? If yes which one? Explain why?

C. Interview guide questions with officials from Rwanda Revenue Authority and district

- ✓ What are the institutions involved in property valuation for taxation purpose and their role?
- ✓ Where do you get data related to taxpayers?
- ✓ Which approach do you use to come up with the land/property tax?
- ✓ What are the types of land/property taxes or fees your institution allow to collect? Which one requires the valuation report?
- ✓ What are the required data for land valuation for taxation purposes?
- ✓ Where do you get these data?
- ✓ Do you save and keep the data related to property value for future reference on land/ property taxation?
- ✓ Are you familiar with remote sensing data like Satellite images, Aircraft images, Drones (UAVs) images, terrestrial images?
- ✓ From the Remote sensing data we discussed above would you consider using them for land/ property taxation? If yes which one? Explain why?
- ✓ Are there any remote sing techniques do you use to monitor and update the taxable properties?
- ✓ Do taxpayers have the right to appeal to the appraised property taxes values?

4. Focus Group Discussion guide question

- ✓ What are the factors that influence the property value?
- ✓ How those factors affect the property value? Would please give each factor the weights ranging from very important to decidedly less important respectively 10 to 1? Explain why?
- ✓ Where do you get data for property valuation for taxation purpose? Do Are there enough/ Complete and updated? (Which institutions are involved in current valuation for taxation purpose?)
- ✓ What are the current methods for data collection for property valuation for taxation purposes?
- ✓ Would you please explain which challenges you are facing regarding data for property valuation for taxation purposes?
- ✓ What have you learnt from these remote sensing techniques compared to the currently used methods for data collection for land/property valuation for taxation purposes? Briefly discuss the similarities and differences
- ✓ Are these remote sensing techniques used to improve the current methods for data collection for property valuation for taxation purposes in Rwanda regarding the completeness, update, and correctness (accuracy)? If yes, which one do you think is more useful? Explain why?
- ✓ Do expect any challenges and limitations that may be faced in Rwanda adopting new technique using remote sensing data for valuation for taxation purposes?
- ✓ What can you suggest/recommend/comments for a new approach for data collection for land/property valuation for taxation purposes?
- ✓ What can you suggest/recommend/comments for the new approach for data collection for land valuation for taxation purpose?

5. Time Planning

	Year	2017																2018										
	Month	September				October				November				December				January				February				March		
	Weeek	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
Activities	Literature review	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Field work preparation	■	■	■	■																							
	Terresterial images acquisition					■																						
	Interviews					■	■																					
	Focus group							■																				
	Transcript of Interview, data interpratation								■	■	■	■																
	Mid-Term presentation											■																
	Data analyis												■	■	■	■	■											
	Evaluation of developed method													■	■	■	■	■	■	■	■							
	Thesis writing and compilation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Thesis submision																								■			
	PowerPoint preparation for Thesis defense																									■		
	Thesis defence																										■	