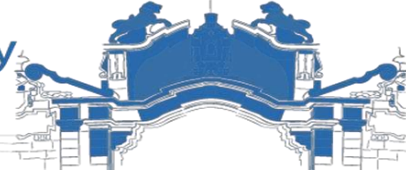




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School of Civil and Environmental Engineering

Department of Geodesy and Geomatics

**Accuracy Assessment of digital parcel map for Second-Level Land Demarcated Parcel in
Case of Guahgot Kebelle, Eastern Tigray**

A Thesis Submitted to the School of Civil and Environmental Engineering of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Geodesy and Geomatics specialization in Geomatics.

By: Haftom Gebremedhin (GSR/ 7440/12)

Advisor: Andenet Ashagrie (PhD)

August, 2024
Addis Ababa, Ethiopia

Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

**Accuracy Assessment of Spatial Data for Second-Level Land Demarcated Parcel in Case of
Guahgot Kebelle, Eastern Tigray**

Haftom Gebremedhin

Approved by board of examiners:

Andenet Ashagrie (PhD)	_____	_____
Advisor	Signature	Date
Internal Examiner	Signature	Date
External Examiner	Signature	Date
School Dean (Chairman)	Signature	Date

Declaration

This is to certify that this research work entitled “Accuracy Assessment of Spatial Data for Second-Level Land Demarcated Parcel in case of Guahgot kebele, Eastern Tigray” is my own work under the supervision of Andenet Ashagrie (PhD). This work has not been presented elsewhere for assessment. All relevant materials used in this research have been duly acknowledged.

Haftom Gebremedhin

Name

Signature

Date

As Master research advisor, I hereby certify that I have read and evaluated this MSc thesis prepared under my guidance.

Andenet Ashagrie (PhD)

Advisor

Signature

Date

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List of abbreviations

ASPRS	American Society for Photogrammetry and Remote Sensing
CSA	Central Statistical Agency
DO	Digital Orthophoto
DPM	Digital parcel map
ELAP	Ethiopia Strengthening Land Administration Program
ELTAP	Ethiopian strengthening Land Tenure and Administration Process
EPLAUA	Environmental Protection Land Use and Administration Authority
FFP	Fit for purpose
GIS	Geographic information system
GPS	Global positioning system
HHGPS	Hand Held Global positioning system
LAC	Land Admiration committee
LIFT	Land information for transformations
MOA	Ministry of Agriculture
MOARD	Ministry of Agriculture and Rural Development
NSSDA	National Standard for Spatial Data Accuracy
REILA	Responsible and Innovative Land Administration in Ethiopia
RMSE	Root mean square error
RMSE _H	The horizontal linear RMSE in the radial direction that includes both x- and y- coordinate errors.
RMSE _X	Linear RMSE in the X direction (Easting)
RMSE _Y	Linear RMSE in the Y direction (Northing)
SLLC	Second level land certification
SLM	Sustainable land management

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Abstract

Rural cadastral mapping in Ethiopia has significantly improved since 2003, when a parcel-based demarcation system replaced the traditional method of registering parcels through written documents. This rural cadastral map aims to comprehensively document the land's history and certify its usage types, including private, communal, state-owned, leased investment lands, and other holdings. During this process, parcels are delineated using printed Orthophoto images created from Remote Sensing or photogrammetric data.

This study examines the horizontal positional accuracy and validation of the digital parcel map using in-situ total station measurements and direct digitization from digital orthophotos. The digital parcel map's horizontal accuracy is evaluated according to ASPRS standards and general boundary criteria, computing the Root Mean Square Error (RMSE) independently for both datasets and the RMSE in radial linear directions using thirty checkpoints. Additionally, the validation of the digital parcel map is based on general boundary principles.

The planimetric accuracy of the digital parcel map for selected sample parcels is assessed using total station measurements, determining the horizontal linear RMSE in the radial direction errors for these parcel corners are 1.697 meters and 1.633 meters, respectively. Furthermore, this study validates the area and perimeter of the digital parcel map using data collected through total station surveys and digital orthophotos. During the validation of area for total parcels within the kebele, 8.21% (446 parcels) fall outside the general boundary standard (with errors exceeding 17%) when compared to field measurements. Additionally, the validation of parcel perimeters process reveals differences ranging from 3.61% to 0.48% for distances of 135 meters and 270.547 meters, respectively, when using the total station. Comparing with digital orthophoto measurements, the differences range from -7.41% to 0.14% for the same distances.

Based on the study findings, the second-level land demarcation process requires modernization to align with ASPRS fixed boundary standards. To achieve better accuracy in digital parcel map, the Rural Land Administration should prioritize the exclusive use of digital orthophotos for large-scale map production.

Keywords: Delineation, Demarcation, Orthophoto, Rural cadaster, Second level land certification, Spatial data,

Chapter One

Introduction

1 Background of the Study

All humankind depends on the land for their basic needs and they use it as a source of income (Dale & McLaughlin, 1988). Most cultures have been built on land and its resources since the beginning of civilization for their requirements in terms of food, shelter, work, resources, and religion, people have been dependent on the land. Whether in an urban or rural setting, land is the foundation of most human activities and development projects. Good administration, safe land and property rights, and economic expansion are essential for maintaining peace and stability of the environment (Minami 2009). The land is managed using various techniques and one of these techniques is implementing land management through cadastral system (McLaughlin & Dale, 1988).

According to the UN Guidelines (UN, 1996), land administration concerns the processes of recording and disseminating information about the ownership, value, use of land, and its associated resources. These procedures involve the identification (sometimes referred to as the "adjudication") of land rights and other characteristics, their comprehensive documentation, their survey and description, and the supply of relative data to assist land markets. A land administration system should provide order and stability in society by creating security not only for landowners and their partners but also for national and international investors and money lenders, for traders and dealers, and for governments.

In Ethiopia; land is a major socio-economic asset. The country's history has been, and continues to be, greatly influenced by the conflict for land ownership. Ethiopian rural land administration has a long history, and it was administered at different times differently because of governance types. There are three distinct periods in the evolution of land tenure policy and changes: the land tenure system prior to 1975, the governance under the Derg regime until 1991, and the era following 1991 (Adenew & Abdi, 2005).

Before 1975, Ethiopia's land tenure system was complex, with strong links to political and class structures, and high regional variation (Deininger, et al., 2008) and most lands were occupied and owned by the feudal, pastorals, and imperials. After 1974 the modern type of land administration was started when Derg comes to power. Derg gives land use rights and introduces prohibition for sale, transfer, and mortgage. Even though Derg introduces the land use right, this type of land tenure had a gap in mapping and the land was owned by husbands only, wives had not right to use their land (Adenew & Abdi, 2005).

The third stage of land tenure began after the fall of the socialist Derg regime in 1991, marking a period of significant changes in Ethiopia's land tenure system. The Rural Land Administration Proclamation No. 89/1997, established in July 1997, represents a recent milestone in the history of land administration in Ethiopia. After 1991, the parcel started registration with both husbands and wives, the main objective of these land registration was to address the problem of tenure, lack of confidence and to establish an effective framework for land administration at the local level (Adenew & Abdi, 2005). One of Africa's biggest, quickest, and least expensive land certification and registration changes has been carried out in Ethiopia. The broad-scale first-stage land registration and certification involved the registration of land registers using simple, locally available technologies that required little training, despite some variation in how land registration and certification have been implemented throughout Ethiopia and even within regions. At this stage, there was no cadastral parcel demarcation; the land history was only recorded in written documents, depending on households. In addition to that, the first-stage certification had limitations with respect to the maintenance and updating of land registration records (Bezu & Holden, 2014).

However, the registration is changed from time to time to modernize registration and to register the accurate cadastral history of the parcel (Adenew & Abdi, 2005). The cadastral map in Ethiopia had been incorporated only for urban areas; however, at this moment, the rural cadastral map was started since 2003. This rural land cadaster records the history of the land from the beginning to certify landholders like private holdings, communal holdings, state holdings, lease investment lands, and other holding types (Hull, 2014). Ethiopia has begun piloting and

introducing a second stage of land registration and certification in selected districts in the highland regions. Under the new registration and certification system, each farm plot's exact location and dimensions are registered using technologies like GPS, Satellite photography, or Aerial photography. Rather than a certificate at the household level, farmers receive certificates at the plot level along with maps. This new technology involves registering and demarcating the land parcel, first by using handheld GPS to certify the parcel rather than the household. Later, geographical land demarcation and registration are undertaken by using Orthophoto to record the history of the parcel (ibid).

According to fit-for-purpose land administration (2016), guiding principles for country implementation states that the accuracy of rural parcel demarcation is understood as a relative issue related to the use of this information rather than being driven by technical standards. In contrast to highly valuable and heavily populated urban areas, where accurate field surveys may occasionally be necessary, rural areas often have less of a requirement for accuracy. The need for accuracy of the various features should be considered and determined by assessing the purpose of using this information to support the various land administration functions of land tenure, land value, land use, and land development.

Therefore, this study was focused on the determination of whether the digital parcel map derived from second-level land demarcation using Orthophoto meets cadastral accuracy standard (spatial data) requires. This assessment involved comparing the digital parcel map against established spatial data accuracy standards, which typically include precision requirements for positional accuracy, area, and perimeter. Total station and direct field demarcating from digital orthophoto were used for the collection of the data, and the error is defined as per the American Society for Photogrammetry and Remote Sensing (ASPRS,2023) standards through the Root Means Square Error (RMSE). In addition to those standards, this study also evaluated the digital parcel map according to Jack McKenna, 2016 Fit for Purpose Parcel Mapping Methodologies for a Seamless Cadaster Database, general area comparison converts from ASPRS 1998 standards. The study was carried out in Guahgot kebele which is located in eastern zone of Tigray, northern Ethiopia.

1.2 Statement of the Problem

Land certification is the right tool for creating tenure security, enhancing farmers' confidence in their land rights and-supported by a proper land use planning system-improving land-related investments and crop productivity. There is currently no enough research addressing the accuracy assessment and validation of digital parcel maps (on rural cadastral map) for second-level land certification in Ethiopia very well in general and the study are in particular. Furthermore, the Second-Level Land Certification (SLLC) program utilizes a general boundary approach rather than a fixed boundary survey . In general boundary demarcation the field map sheet was prepared at a scale of 1:2000 (where 1 mm on the map corresponds to 2 m on the ground and measuring 1mm in map is difficult). Additionally,To address unclear parcel boundaries, tape measurements are used to determine corners, but transferring these measurements to the orthophoto becomes challenging due to the irregular shape of the parcel. Furthermore, the unfamiliarity with the results within the community arises from the scale, making it difficult for them to understand the demarcated parcels from the Orthophoto and verify their respective areas .

Therefore, this study was intended to assess the spatial planimetric (horizontal) accuracy, validates parcel area and perimeter within the spatial data sources of second-level rural land parcels, used for certification production. This assessment and validation of digital parcel map is useful to the study kebele in particular and other sites in general. They will be able to analyze and update the procedures of the second-level land registration and demarcation program, as well as assess and enhance the current parcel demarcation techniques, with the aid of the created data and information.

1.3 Objective of the Study

1.3.1 General Objectives

The general objective of this study was to assess the accuracy of digital parcel map for second level land demarcated parcel in the case of Guahgot kebele, eastern Tigray.

1.3.2 Specific Objectives

The specific objectives of this study were:

- ✓ to asses horizontal accuracy of digital parcel map for second level land demarcated parcel from Orthophoto field map sheet;
- ✓ to validate the area and perimeter of the digital parcel map.

1.4. Significance of the Study

The findings of the study will have significant importance to different bodies and beneficiaries. The study investigated the spatial planimetric (horizontal) accuracy, validates parcel area and perimeter within the spatial data sources of second-level rural land parcels, used for certification production. Hence, the results are very helpful to the study site, wereda, region and federal rural land administration offices. It will help them to improve the process, evaluate the existing parcel demarcation methods, and revise or review the methods of the second-level land registration and demarcation program. In addition to that, this study help students and researchers as a reference about digital parcel maps for second-level land certification. Furthermore, this study will contribute to modernizing the existing demarcation techniques by providing accurate and reliable spatial data. Furthermore, the results might help to strengthen the global knowledge in digital parcel maps.

1.5 Scope of the Study

This study was aimed to assess the horizontal accuracy and validates of rural land demarcation and registration processes. It focused in assessment of horizontal accuracy, validating the parcel area, and perimeter among the digital parcel map, digital Orthophoto, and measured quantity by using a total station measurements. The demarcated parcel on the orthophoto sheet and spatial data of the Kebele was obtained from Wereda rural land administration, and the measurement of the x and y coordinates as well as direct demarcation on the digital orthophoto were measured from the field and validated using ArcGIS software. It was conducted in one kebele only due to financial, logistic and time shortage. It was geographically limited to one kebele and this might have impact on the reliability of the results.

1.6 Research question

- ✓ Does the digital parcel map derived from second-level land data demarcated from orthophotos, meet the spatial data accuracy standards?
- ✓ Are the area and perimeter of the digital parcel map valid?

1.7. Limitation of the study

This study faced a limitation due to the unavailability of up-to-date digital spatial data, which includes orthophotos and digital parcel maps. As a result, the research had to rely on a digital dataset that was approximately eight to nine years old. Additionally, this study was geographically restricted to being conducted in only one kebele. Consequently, the findings cannot be generalized to the entire woreda, region or country.

1.8. Structure of the thesis

This thesis comprises five chapters, each addressing specific aspects of the research. The first section includes a detailed discussion of the background and the general overview of land tenure. Within this chapter, crucial components such as the statement of the problem, research objectives, significance of the study, scope of the study, study questions, and research limitations are incorporated. Chapter two integrates a conceptual framework focusing on the history of land registration and demarcation in Ethiopia. The general perspective of boundary, spatial data, and accuracy standards with assessment methods are reviewed, and the source of digital spatial data is discussed. This chapter also discusses the land administration system and cadastral system. Moving forward, Chapter three offers a general description of the study area, outlining the data, software, materials, and methods employed for accuracy assessment. Chapter four discusses the accuracy assessment results of the accuracy assessment derived from the digital spatial data utilized in the study, providing a thorough discussion of the findings. Finally, Chapter five is about conclusion and recommendations: Based on the result, this thesis concludes and recommends for future works.

Chapter Two

2. Literature Review

2.1 Cadaster, cadastral system and cadastral map

2.1.1 Cadaster

International Federation of Surveyors (FIG, 1995), defines cadaster as a “parcel-based and up-to-date land information system containing a record of interests in land (e.g., rights, restrictions, and responsibilities).It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, ownership, or control of those interests, and often the value of parcels and their improvements. It may be established for fiscal purposes (valuation and taxation), and legal purposes (conveyance), to assist in the management of land and land-use control (planning and administration), and to enable sustainable development and environmental improvement.

Cadastre is a technical word for a set of an official register of size, value, and ownership of the parcel. It is a record of the area, value, and property holder that initially was collected for determinations of allocating tax (Binns, 1995). In addition to that, a cadaster is a collection of documents and records that describe the value of land and ownership (Muilu & Onkalo, 2006), which supports parcel registration and the collection of different evidence for land registration (Bogaerts & Zevenbergen, 2001). The cadastre provides an organized means of detailed description and documentation of particular pieces of land, and it contributes to continuous history records of rights in land (Binns,1995). It includes different types of purposes, such as legal: a register of ownership of the property land parcel; fiscal: a register of properties recording their value to support taxation; land use: a register of land use; and when a cadastre serves as a supplier of up-to-date and reliable land information at an affordable cost, it is then termed a multipurpose cadastre. The objective of the multipurpose cadastre is to provide a service through which the dynamics of the land parcel may be studied and also meet the demands of the evolution of LAS, which means the needs of the users (Tuladhar, 1998).

2.1.2 Cadastral system

The cadastral system establishes essential land administration functions and is part of the task of land administration, including the administration and management of land tenure, land use, and

land development. It is the most important part of land management, it creates cadastral information, which is necessary for making and implementing various decisions regarding land. This system is used to determine the geographic location of land parcels, define boundaries, and provide parcel sizes. It is not an end in itself; rather, they are a means to support a variety of purposes and facilitate the administration of three main parts: Land tenure, land use, and land value (Chekole et al., 2020).

The cadastral system comprises both land registration and cadaster. The recording of legal documentation of land properties is Registration whereas cadaster refers to input data for land registration (Bogaerts & Zevenbergen, 2001). Digital cadastral maps are one product of the cadastral system; a map that is prepared from cadastral information or parcel-based Cadastral Information System maps all parcel's in appropriate locations and corrects geometric representations (Zegeye, 2019). It is an important part of any cadastral system; shows spatial and attribute information and it is not a hard copy but it is a soft copy map (Cichocinski, 1999).

Cadastral systems generate the cadastral information needed to make and implement a variety of land-related decisions. This includes plot locations, defines boundaries, and specifies plot sizes. All these information products are basic information for the land allocation process, property valuation, and reduction of land conflicts and disputes. An intelligent system is not an end in itself. Rather, it is a means to support various ends (Chekole, et al., 2020).

More concisely, a cadastral system consists of the collection, recording, and storage of all information related to individual land parcels. Cadastral surveying is that which establishes and records the location, boundaries of features thereon, and ownership of land and property. This is one of the data sources in Geographic Information System (Zegeye, 2019).

2.1.3. Cadastral map

Cadastral maps displaying the dimensions and placement of every parcel concerning neighboring properties, water bodies, highways, and other significant geographic features must be available throughout the whole assessment jurisdiction. The maps ought to be created at a suitable scale, showing all areas, dimensions, and boundary lines, as well as parcel numbers and other relevant descriptive and legal data. Non-physical parcel information, such as assessment comparisons,

land appraisals, and market or other statistical data, can be shown on the maps' physical framework. Additional fundamental map data that should be included on cadastral maps include a map number, the date the map was created, a scale, a revision block, a legend, a map key, a north arrow, and a key to Digital cadastral maps provide tremendous value to the assessor and numerous other users in a parcel data-sharing environment. Digital maps are an integral part of a comprehensive assessment system, without which a complete picture of the interests and value of the land and improvements to it is not possible (O’Neill & Davis, 2018).

2.1.4 Map Scales

A map scale that covers the largest possible area while showing necessary detail should be selected. The main determinants of map scale selection are the size of the area covered by a map and the complexity of the parcel features. In general, they recommend using large-scale maps for urban and suburban areas and small-scale maps for rural areas. Map scales should be expressed in ratios that can be easily converted from the imperial system to the metric system (O’Neill & Davis, 2018). According to Enemark, (2016), the scale for different areas as follows:

Table 2. 11. Scale for different areas adopted from FFPLA

Area	Mapping applications
Urban central High density, high value	Dense development and very high land values require large-scale mapping to be performed by conventional terrestrial surveys or large-scale image maps with a preferred scale of 1:500 – 1:2,000
Residential urban Medium density, high value	In residential areas, the dwellings and parcels are normally easily identified in image maps imagery to a scale of 1:1,000 – 1:2,000.
Peri-urban Mixed density, good value	Peri-urban areas include a mix of land uses that will require image maps to a scale of 1:2000 – 1:5000 depending on the density and complexity of developments.
Informal/slum Very density high	Slum areas can be mapped for many purposes. An option is use UAVs for mapping to a preferred scale of say 1:500 – 1:2,000. Individual housing structures can then be identified for administration and service delivery.
Small towns, villages High	Rural villages may be mapped separately e.g. using UAV to a

density, low value	scales of 1:2,000, or they may be mapped as part of a major rural area
Rural agricultural medium density, good agricultural value	In rural agricultural areas, the individual parcels will normally be visible on satellite image maps to a scale of 1:2,000 – 1:5,000.
Rural remote, forest density, low value	Low Mapping more remote rural areas may serve various purposes, such as land rights, natural resource management, water catchment, etc. Satellite image maps to a scale of 1:5,000 – 1:10,000 will normally be sufficient.
Rural mountainous	Mountainous areas can be covered by satellite image maps to a scale of 1:5,000 – 1:50,000 depending on the topography and settlement activity.

2.2 Rural Cadastral System Policy in Ethiopia

The land tenure system in Ethiopia is a reflection of conflicting and long-standing historical issues, such as the consequences of military control to address feudal abuses and feudal traditions itself. Regardless of the type of government in place, the state has always maintained a strong degree of control over the distribution and use of land. Both the Marxist regime (the Derg) and imperial control made attempts to modernize land ownership by granting title to peasants who cultivated the soil or to large-scale farms and cooperatives (Degife et al., 2018).

July 1997 marked the enactment of the "Federal Rural Land Administration Proclamation" (Proclamation 89/1997) (FDRE, 1997). The proclamation gives regional governments power over land administration, including the distribution of land rights, and grants them authority over the "assignment of holding rights and the execution of the distribution of holdings". However, it also places restrictions on how regional administrations can use these powers. The proclamation's preamble forbids selling or mortgaging land, thereby reaffirming the constitutional assertion that the state has the exclusive right to ownership of land. It also maintains that the regional governments' transfer of land ownership is lawful.

Ethiopian rural land cadaster does not yet have a long history, it is at the starting period following the new method of data collection to record the history of parcel land from the beginning to certify the landholders like private, communal, state, and leased lands and for other decision-makers. (Hull, 2014). In Ethiopia; Cadaster was started for the first time in 1909 in Addis Ababa city; the Ministry of Land Reform and Administration was established in Emperor HaileSelassie's governance time to ownership tenure, provide individual titles of land, and facilitate land sales cooperation with the Mapping Agency until 1974 (Steudler, et al.,2004). In 2005, a Rural Land Administration and Use proclamation were drafted by Ministry of Agriculture and Rural Development (MOARD) and presented to the Parliament for approval. The objective of this bill is to conserve and develop the nation's various ecosystems and set up a land administration system that will identify federal and state lands and current user rights being practiced (Adenew & Abdi, 2005). Currently, regional and federal governments are involved in the cadastral systems. The federal government is accountable for developing laws, policies, and frameworks for land and other natural resources (Hull, 2014).

2.3 Rural land registration

The formal recording of land rights through titles to properties or through deeds is known as land registration. That indicates that there is a formal record (land register) of land rights or deeds pertaining to modifications to the legal status of specific land units. The queries of who and how are addressed. Since they are interactive systems, cadaster and land registration typically work well together. A cadastre places more emphasis on the relation right-object than land registration, which in general emphasizes the relationship subject-right. In other words, the land registration answers the questions as to who and how, and the cadastre answers the questions as to where and how much (Kaufmann & Steudler, 1998).

There has never been a systematic rural land registration system in Ethiopia. Before 1974, when the Imperial rule was in place, landowners used local units of measurement to register the size of every plot of land they owned in order to facilitate tax collection. In most cases, agreements about the usage of land were verified in front of witnesses rather than through written documentation. The land was measured, and the owners possessed documents attesting to its ownership and use, such as for residences, businesses, etc. Land management and registration

fell within the purview of the town municipalities. Following the 1974 land reform, the newly formed lower administrative entities, known as peasant associations, were granted the authority to register land inside the boundaries of the responsibilities they oversaw. The land registry listed the names of all peasant association members entitled to user rights over land, an estimation of the area and quality (in local units of measurement), the number of parcels, and the approximate location of landholdings. The information collected in the registry was used for taxation and during land redistribution activities. The user of the land has no documentation themselves, except for the tax receipts. Since 1991, lands have continued to remain state property, and the local administrations in rural kebele continue to manage land issues. The registry still lists the community members who hold land and some basic elements, such as approximate size and location, that are used to collect land tax (Adenew & Abdi, 2005).

2.4 Rural land demarcation in Ethiopia

Demarcation is referred to as a process of parcel delineation, defining the title of the parcel, and is applied to individuals and groups. It is costly to undertake and has rarely been used to secure individual plots in rural areas, largely because, in the context of shifting agriculture, it has not been economically viable (Norfolk & Bechtel, 2013). Traditionally, in Ethiopia, rural land was demarcated with the mark feature, mostly with stones, trees, and wooden stakes in the corner of the parcel, but due to the irregular shape of the parcel, the exact boundary was not shown (Bezu & Holden, 2014). Currently, parcel map production is the most commonly practical method for mass land registration. It is carried out using orthophoto field map sheets prepared from aerial photographs or satellite images after various corrections are made. These orthophoto maps are prepared and printed as both field maps and index map sheets according to defined cadastral standards, and then taken to the field to demarcate the parcel land for the registration process. In the demarcation process, the parcel holder shows the boundary of the parcel to demarcate the surveyor in the orthophoto. Once the surveyor has manually sketched the parcel on the orthophoto sheet, the orthophoto sheets are scanned, geo-referenced, and then digitized (Zein, 2017).

2.5 First level land certification

Ethiopian land registration started in 1998 with a program in Tigray and expanded to the Amhara, Southern Nations Nationalities and Peoples (SNNP) and Oromia. according to the Rural Land Use Directorate at the Ministry of Agriculture, more than 90% of farming households in these regions received their land certificates through first-stage registration (Adenew & Abdi, 2005).

This first level certification involved registering the rights of these households and issuing books of holdings, or “green books,” listing holders’ names, approximate parcel areas, and neighbors’ names. However, no maps have been produced, as parcel boundaries have not been surveyed (Enemark et al., 2014). First-level land certification, according to the Ethiopian Ministry of Agriculture (MoA) is the process of giving farmers temporary landholding certificates without any mapping information about the individual parcels of land (Bezu & Holden, 2014) .

Bezu & Holden (2014) state that qualified surveyors were not required for the initial stages of land certification and registration. Low-cost certification and registration: Compared to technically difficult registration, millions of agriculture plots might be registered in less time. Transparency was achieved through broad participation and the conflict resolution system builds on existing systems through the use of local conflict mediators and social courts and is supplemented with newly established local land administrative committees. But maintenance of records (the registry books are difficult to update in the event of land inheritances, gifts, or divisions due to divorce.), registered to households (not registered by landholders), but not plots, don't have unique identification numbers, The certificate does not contain maps of the farm plots and Accessing information for land administration and policy analysis is difficult, as data registration is paper-based and not easily available.

2.6 Second level land certification

The second-level land certification program is the method of certifying and registering a plot of parcels by using measuring coordinates obtained from the Handheld GPS and Orthophoto system. To implement the SLLC program LIFT, SLMP, and governments are involved in covering the country in a short period (Hagos, et al., 2016). SLLC adds a spatial component to first-level certification. This is a parcel map, supplied to the right holder in hard copy and maintained

digitally at the woreda level. The more permanent second-stage certificate, therefore, “seeks to rectify the weaknesses in the Stage 1 land certification, particularly the need to geo-reference and map individual parcels to avoid or minimize boundary disputes.” According to MOA, the second-stage certification's objective is to enhance tenure security for smallholder farmers (Bezu & Holden, 2014). Trials for cadastral mapping were conducted using 40 cm resolution orthorectified aerial photographs captured and processed by the Ethiopian Mapping Agency (EMA). A3 size printed field map sheets at a scale of 1:2,000 were typically used. In the trial, the ‘General boundaries’ principles were applied to demarcate parcel boundaries. The surveyors marked boundaries identified on the ground onto the orthophoto image and gave the land parcel a unique parcel identification number. During the fieldwork, parcel boundaries were initially drawn on the orthophotos using pencils. The para-surveyor drew the boundary lines on the field map sheet after confirmation of the boundary by the owner of the subject parcel and the neighboring holders, facilitated by the Land Administration & Use Committee member. Then a unique parcel identification number was allocated for the demarcated parcel. When the para-surveyor assigns a unique parcel identification number to the demarcated parcel, he or she communicates with the field data recorder for textual data recording. Owner and parcel details are recorded on the field form prepared for this purpose. Disputes and encumbrances, if any, are recorded by the field data recorder immediately after parcel number allocation. Office work includes scanning, geo-referencing and digitizing, attribute recording, and quality control. Then a public inspection is completed. After any corrections the parcel maps can be produced (Hailu, et al., 2016).

2.7 Role of Digital Satellite image and Photogrammetry for SLLC demarcation

A remote sensing system is preferable for covering a wide area and provides every time digital images more frequently and low-cost related to aerial photos (Jeong, 2016). It is important for preparing Orthophoto used for delineating, correcting, and transferring parcels in Cadastre. In addition to that it provides continuous historical records of the area, and helps to reuse again to check the rate of change. In this way, the previous image provides tangible evidence where conflicts arise in parcel boundaries. Remote sensing images are used as an additional source to common land surveying methods for spatial data determination where most measurements can be done in the office (Ali, 2013). The use of remote sensing (RS) images can play an important role

in updating and extracting land-related information. One advantage of using RS images is that they provide a historical record of the areas that can be revisited in the future to see what changes have taken place. In this way, old images can provide valuable evidence where conflicts occur in parcel boundaries. Furthermore, traditional land surveying approaches are time-consuming and require a lot of effort. Sometimes it is very difficult to do cadastral surveys in remote areas, especially in mountainous areas when the weather is very harsh. In this case, RS images can be used as an alternative to the traditional land surveying approach for spatial data acquisition where most measurements can be done in the office (Ali & Ahmed, 2013).

Photogrammetric surveying also another option system to a terrestrial method of data collection, and this practice developed common and used by different states for improving land administration methods. Digital photogrammetry produces quantitative feature information such as size, shape, height, and spacing of features of images (Sisay et al., 2017). A Digital Orthophoto is prepared from the digital image after such corrections are applied like tone matching, scaling, rectifying, and vector/annotation. The use of aerial/satellite imagery for providing the spatial framework will be sufficient for most land administration purposes. Evidence shows that this approach is three to five times cheaper than field surveys and much less time and capacity-demanding. The required scale of the mapping depends on topography and density of development and may vary from large-scale orthophotos (1:500 – 1:1,000) in dense urban areas to smaller-scale imagery (1:2,000 – 1:10,000) in rural areas and remote regions. Boundaries can easily be identified on the imagery in most cases, depending on the visibility of the physical features. Experiences in Rwanda and Ethiopia, for example, show that citizens have good spatial cognizance (Lemmen et al., 2009).

2.8 Boundary concepts

According to Williamson, (2010), the term "boundary" can refer to either the actual objects that delineate the boundaries of a property or the imaginary line or surface that divides two legal estates. It can also refer to the division between features that have distinct administrative, legal, land use, and topographical characteristics. Specific boundaries, sometimes known as "fixed" boundaries, can have their exact line determined through field surveys or descriptions. Another category of boundary is termed as "general" in which case the precise line has not been

determined and the register only show the approximate line of the boundary, such as physical features in the field shown on large-scale mapping. The parcel is then positioned concerning certain physically visible features, however, it is not explicitly stated how these features relate to the boundary (Lemmen et al., 2015).

2.8.1 General boundary

General boundaries are not surveyed accurately and boundary lines are demarcated by existing physical feature such as walls fences and hedges. Dale & Mc Laughlin (1999) defined general boundaries as the approximate lines of the boundary, where by the precise details can only be established through further investigation. The vagueness of such a boundary system allows for the land register to ignore shifts in the agreed position of the parcel corner (Tuladhar, 2006). This method is appropriate in rural areas of developing countries where accuracy is of little concern. The establishment of general boundaries in this area can be done through photogrammetric means which is generally more cost effective and efficient than fixed boundary system (Lemmens, 2015).

2.8.2 Visible (physical) boundaries rather than fixed boundaries

Using a "visible boundaries" (general boundaries) approach makes it simple to identify the boundaries by their outward appearance in aerial or satellite imagery, and it allows local stakeholders to participate in a participatory process to directly identify the connected land rights. Of course, not every boundary will be shown in the images. Complementary field surveys are required to capture these invisible borders (Enemark, 2016).

In densely populated, highly valuable metropolitan regions, a fixed boundary approach might also make sense. So, the principle should rather be understood as a predominant use of visible rather than fixed boundaries. In cases where there is a specific need or wish to determine the exact boundary line using a fixed boundary approach then this can be met by using field surveys to be paid for by the parties. The boundary will then be recorded as "fixed" and the surveys will be filed in the system as evidence of the exact location. Even while the boundaries appear as physical characteristics on the field, they could not be visible from the air in forestry areas, for example. Some limits, though recognized and acknowledged by those involved, may not even be

physically visible. The FFP method, in comparison, is adaptable concerning accuracy and the range of tenure types that can be secured, whereas traditional cadastral systems are fairly standardized. It is possible to gradually upgrade and enhance the land management system over time (ibid).

2.8.3 Area Computation of General Boundary

According to MCKanna,2016 converts from ASPRS, 1998 area of a hypothetical parcel area is calculated using fixed boundary survey coordinates values (theoretical 100% precision) and using general boundary coordinate values (a 3-meter off-set to reflect the maximum error obtained from a 1:2,000 digital Orthophoto). The maximum coordinate offset (outward or inward) results in an area calculation for the parcel that is within 8% - 17% of the actual parcel area. It should be noted that a coordinate error of 3 meters is associated with mapping accuracy.

2.9 Spatial Data and spatial data sources for cadastre

Spatial data are a representation of the real surface by their basic characteristics of the data which are separated by geographic features (point, line, and polygon), and their attributes, geographic features are reasonably organized into sets of layers. Mainly cadastral maps are organized into layers such as parcel boundary, current land use, land classification type, and buildings (Cichocinski,1999). It also is defined as an easy representation, or model consisting of locations, shapes, and relationships of a geographical phenomenon, both natural features, and arterial made, as connected with the surface or near-surface of the earth (Weng, 2009). It contains the relative geographic information of the earth's surface and features, this data comprises the geographic location of points or features described using latitude and longitude coordinates. Based on the storing method spatial data are raster and vector data. Raster data are characterized by pixels or grid cells described by columns and rows. Vectors represent features by using points, lines, and polygons (Janipella & Moharir 2019).

The creation of spatial data is very expensive involving largely complex data exchange from survey-collected data and analog maps, especially when very accurate data is needed as is the case for utility and cadastral applications (Adler, 2001).Using remote sensing and photogrammetry methods of data collection became the choice of advanced technology to collect

digital spatial data for ground features to determine spatial data and is Most important for cartographers in providing data used for mapping. Currently, spatial data extracted from satellite images and aerial photos are a major source of data for mapping a given area (Vieira et al., 2002).

2.10 Spatial Data Accuracy

Accuracy is the degree to which information on a map or in a digital database is close to actual (true) or acceptable value. The difference between the measured (recorded) and actual value of certain characteristics of a given unit is defined as an error. It is an issue that concerns the quality of data and the number of errors that happen in a data set or map. Determining a high level of accuracy in different applications varies according to cost, procedure, and compiles. In geographic or spatial data accuracy the error or standard level is determined according to the point, line, and area. For points, accuracy is defined in terms of the distance between the encoded location and the actual location. The horizontal accuracy of the map is determined by Root to mean square errors of the maps of X_Coordinate and Y_Coordinate for examination points. The error determines the cumulative square difference between the coordinate of the map and the measured coordinate divided by several testes then put in the radical, this type of error is RMSE (ASPRS, 2023). Depending on the (ASPRS, 1998) standard for map scale 1:2000 class I accuracy of the digital data should be less than or equal to 0.5m for class I, for class II and class III with the same scale the RMSE should be 1, and 1.5m respectively.

2.11 Accuracy relates to the purpose rather than technical standards

Accuracy of the land information should be understood as a relative issue related to the use of this information, rather than being driven by technical standards that are often inflexible and “over the top” for the purpose. In general, the need for accuracy is lower in rural areas than in densely built-up and high-value urban regions, where accurate field surveys may sometimes be justified. Technology development has provided a range of very useful and affordable opportunities for producing the spatial framework on various scales and suitable for various purposes. The registration of legal and social tenure rights requires identification of objects but the process does not call for high accuracy per se. The identification through visible boundaries will be sufficient for securing and recording the legal and social land rights (Enemark & Lemmen, 2016).

Nonvisible boundaries can be captured by supplementary measurement in the field with sufficient accuracy to allocate the non-visible boundary on the map. If parties want the exact boundary determined for a specific purpose, then it can be measured and registered at their cost. The function of valuation and taxation needs a map with identification (cadastral numbers) of the individual parcels and properties. Valuation does not need measurements or exact identification of boundaries. The scale of the mapping needs to be sufficient to identify objects in the field and to calculate the area of the object. FFP approach to building the nationwide spatial framework that could be termed “a continuum of accuracy”. This relates to the opportunity for continuous updating and upgrading of the system to a continuously improved accuracy. It must be noted, however, that quality is not just about spatial accuracy, there are other quality dimensions to be taken into account; especially about ensuring that the accuracy relates to the purpose and is balanced against the costs, time, and capacity needed for providing this quality (ibid).

According to Jack McKenna (2016): Most countries that use modern GIS, total station, GPS, and photogrammetric mapping techniques to create a contiguous parcel database (cadastre) for the calculation of property taxes primarily use the general boundary survey methodology to create a database of calculated parcel areas based on general boundary parcel corner coordinates. Because of the reality that the resulting calculated areas are in error from 8% to 17% for ASPRS Class I to Class III mapping at a scale of 1:2,000 the billing area for each parcel could be reduced by 10%. That is, if the parcel area calculated from a general boundary survey is, for example, 2.39 Ha, then the area billed by the tax office could be 2.39 Ha less 0.24 Ha, or 2.15 Ha. This 10% buffer ensures that owners have confidence that they are not being over-billed for the taxes associated with their property.

Table 2. 2. General boundary standards adopted from Mckenna, 2016

Map Scale	Class1	Class 2	Class 3	Map type
1:5,000	99%	98%	97%	(20 Ha parcel)
1:5,000	98%	96%	93%	(5 Ha parcel)
1:5,000	97%	93%	90%	(2 Ha parcel)
1:2,000	97%	95%	92%	(0.5 Ha parcel)
1:2,000	94%	88%	83%	(0.1 Ha parcel)
1:1,250	88%	-	-	(0.1 Ha parcel)

CHAPTER THREE

3. MATERIAL AND METHODS

3.1 Descriptions of the Study Area

Kebelle Guahgot is found in the northern part of Ethiopia, specifically in the Tigray region, eastern zone, Wereda Ganta-Afeshum. It is located between 14°8' N and 14°12' N latitude and 39°24' E and 39°28' E longitude. The average elevation of the area is approximately 2550m above mean sea level. According to the Central Statistics Agency (CSA, 2007) Kebelle boundary, the total area of this Kebelle is 21.97 km² or 2197.21 hectares. Within the total Kebelle, 1938.49 hectares (88.22% of total area) are demarcated, while the remaining 258.72ha are communal land. The total number of parcels in the Kebelle is 5424 and 2839 parcels area have ≤ 0.1 ha. Located 9km south of Adigrat, the geographical configuration of the Kebelle includes both undulated and flat terrain, and its climate condition is classified as Dega. The Kebelle consists of four sub-Kebelles, with all the parcels being demarcated and certified for parcel holders. Excluded from this certification are areas like trails (footpaths), rivers, grazing land, and other communal lands, which pose challenges for demarcation.

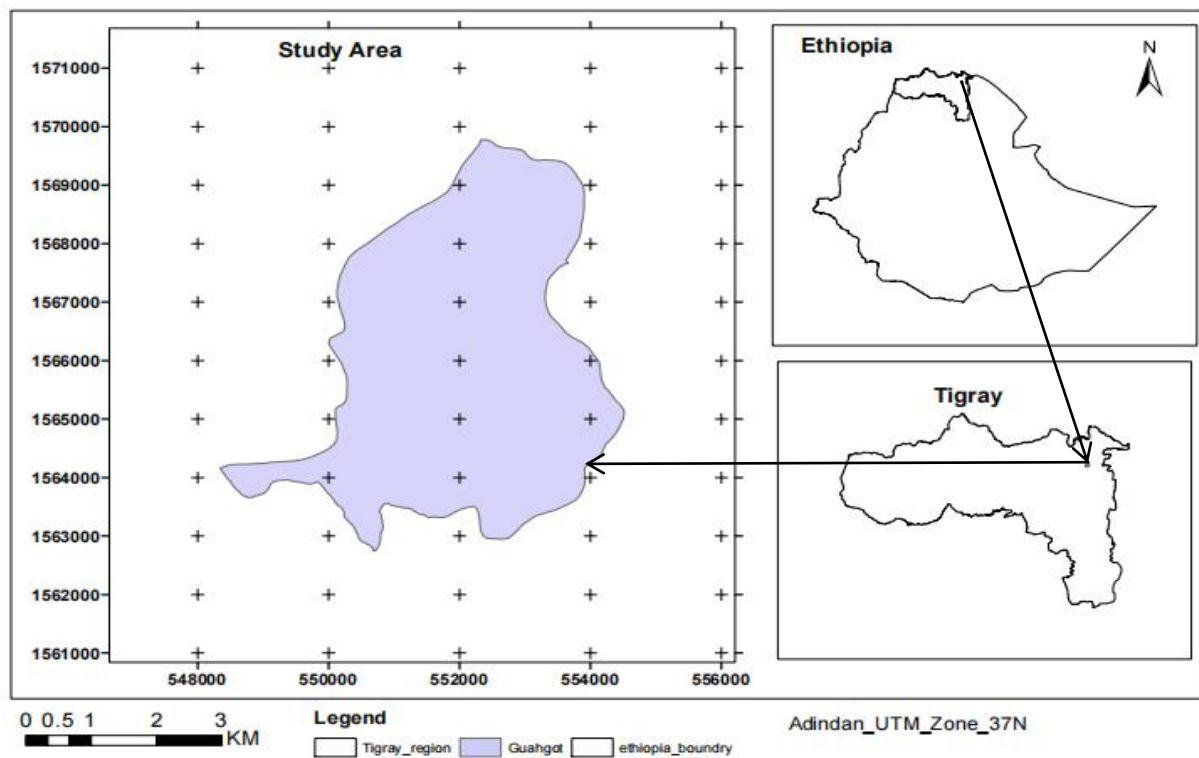


Figure 3. 1. Location map of the study area

3.2. Data acquisition, software, and materials

3.2.1. Data acquisition

For this research, the information presented herein were collected through the use of both primary and secondary data collection techniques. The primary data source involved the direct collection of information in the field (in-situ), while the secondary data was obtained from the Tigray Region Environmental Protection Land Administration and Land Use Agency, as well as from Wereda Ganta-Afeshum Rural Land Administration Offices. The primary data were gathered using total station and digital orthophoto during fieldwork. In general, all necessary information from both primary and secondary data sources were collected during data collection.

Primary data collection methods

- All x, y of parcel corner, area, and perimeter of parcels were collected using total station and digital orthophoto in field.
- X, Y coordinates were measured from digital orthophoto and/or parcel holding certificates for navigating to the sample parcel using handheld GPS.

Secondary data collection methods

Digital orthophoto of the study area was collected from the Tigray Region Environmental Protection Land Administration and Land Use Agency and Wereda Ganta-Afeshum Rural Land Administration Offices. As well as the Digital parcel map of the study area were also collected from Wereda Ganta-Afeshum Rural Land Administration Offices. This spatial data contains digitized parcels map and digital orthophoto. Reference control points were collected from Adigrat municipality and used to run reference control points around the study area using differential GPS. Those secondary data were used to compare results obtained from the primary data measurement.

3.2.2. Software and materials

In this study Arc GIS 10.7 and QGIS 3.8, was used to gather, manage, analysis and summarize data.

Table 3. 1. Soft-wares and materials used during the study period

No.	Name	Purpose	Remark
A. Software used			
1.	ARC GIS and QGIS	<ul style="list-style-type: none"> ✓ Used for parcel database creation (shapefile) ✓ Overlay spatial data and Orthophoto ✓ To calculate area, check topology 	GIS software (ARC GIS10.7, QGIS3.2)
B. Material used -In this study Total station, Hand-Held GPS and Digital and hard copy Orthophoto was used			
1	Total station	<ul style="list-style-type: none"> ✓ To collect the location (x, y, and Z coordinate) of the parcel ✓ To calculate the area of the parcel plot in the field 	To measure accurate Field data
2	Hand-Held GPS	✓ For navigating to the selected parcel	
3.	Digital Orthophoto	<ul style="list-style-type: none"> ✓ Used to demarcate the parcel in the field ✓ To identify the parcel boundary 	Should be geographically corrected

3.3. Sample selection and Methods

3.3.1. Sample selection

For this research purpose, the selected samples incorporated point and polygon. The samples were selected based on the American Society for Photogrammetry and Remote Sensing (ASPRS, 2023), which are distributed over the geographic extent of the image and well defined, easily identifiable features are selected. The selected Kebele, namely Guahgot, has four sub-Kebelles (village administration) and the land administration committee also delegated from sub-Kebelle during the sample selection and demarcation process. On these four sub-Kebelles, the samples were selected randomly but it is considering the geographical distribution to balance.

According to the American Society for Photogrammetry and Remote Sensing (ASPRS, 2023), recently developed new geo-location accuracy standards for digital geospatial data recommend 30 clearly defined checkpoints are needed for a project area of $\leq 500 \text{ km}^2$. According to this standard, 30 check points are enough to evaluate the accuracy. Hence, for this research work, 30 points and 60 parcel areas were collected during demarcation in field using digital orthophoto. In addition to this, 30 points and 70 parcel areas were also measured by using total station. Furthermore, for validation of perimeter, 18 parcels were collected in both total station survey and direct field demarcation using digital orthophotos.

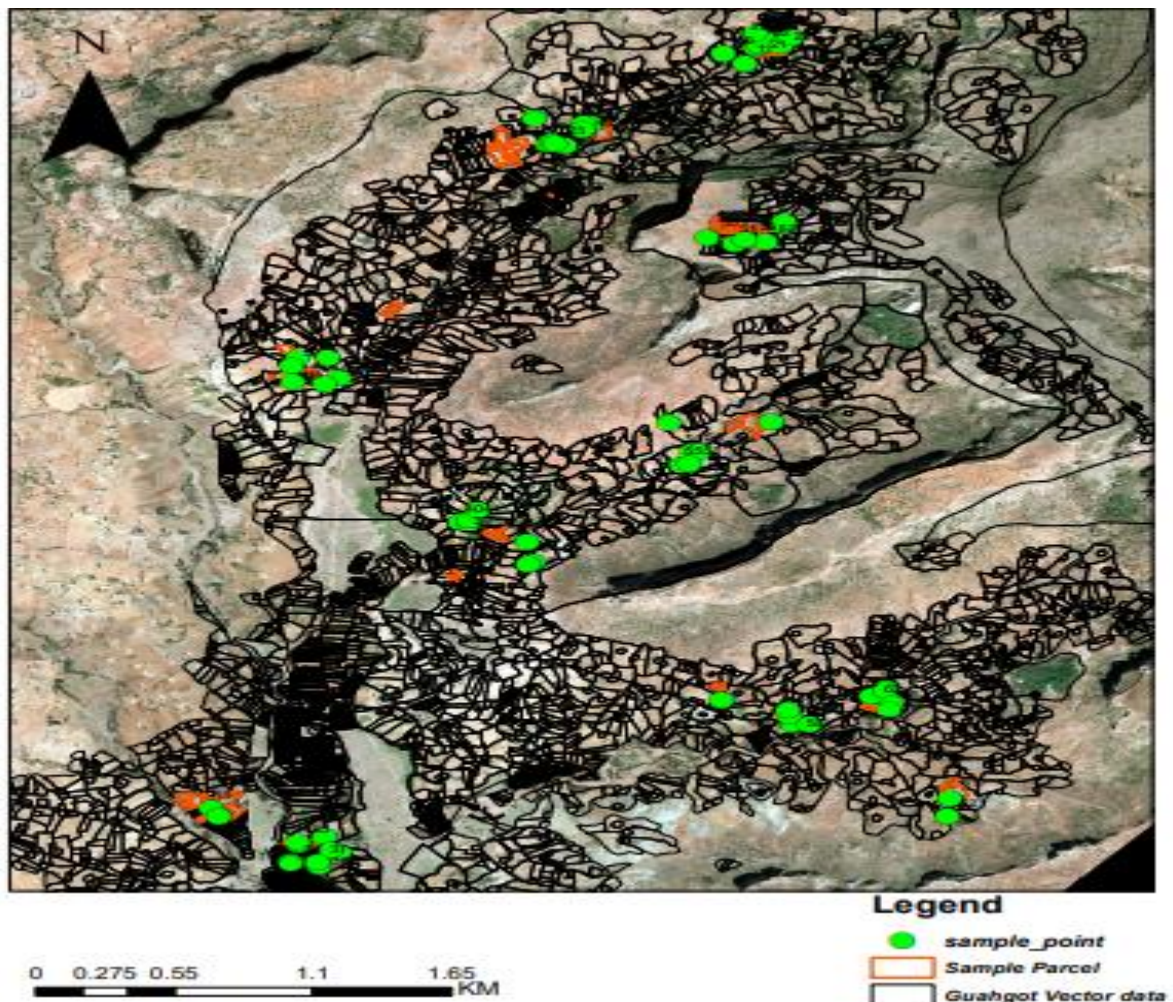


Figure 3. 2. The sample data distribution

3.3.2 Research Methods

This study evaluated the horizontal accuracy of the digital parcel by comparing it with total station and digital orthophoto measurements, following ASPRS standards. Furthermore, the area and perimeter were validated according to ASPRS, 1990 General boundary area standard converted by Jack McKenna (2016).

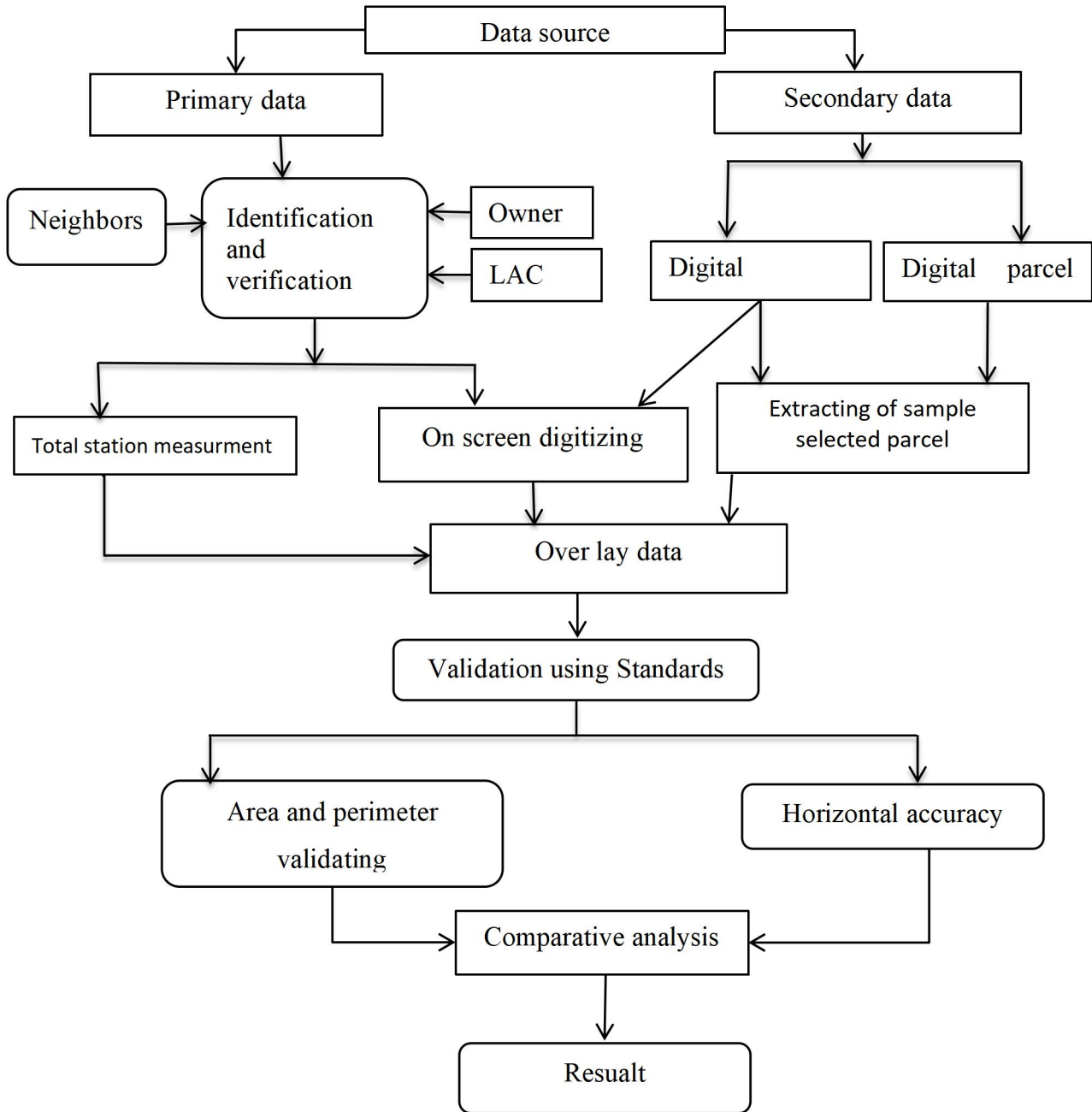


Figure 3. 3. The research methodology

3.3.3 Physical Observation

Direct observation constituted a major data collection tool both at the reconnaissance (site visit) stage and during actual survey. To facilitate rapid interpretation of observed features, observations and data collection were aided by index map, Orthophoto field map sheet and digital Orthophoto.

3.4 Data analysis

For the case of this study, the measured data and digital parcel map were analyzed using Arc GIS. The data gathered in the field was collected using total station and digital orthophoto then the variation was determined by comparing to digital parcel map. According to ASPRS, 2023 standards, the horizontal accuracy was determined in terms of Root-Mean-Square Error (RMSE). Spatial data RMSE is the square root of the average of the difference between data set coordinate values and check survey coordinate values for identical points. The RMSE of each component was determined and reported separately.

In addition to the assessment of horizontal accuracy, the validation of parcel area and perimeter was also evaluated according to the ASPRS standard. Furthermore, this process included an evaluation of the General Boundary standard, which allows a deviation of up to 3 meters from the actual boundary.

3.5 Survey instruments preparation

Before the fieldwork was started, all survey instruments were checked and prepared carefully. This was done at the office of Mekelle University three days before the fieldwork. Two Leica total stations with all the accessories, and two Leica total stations batteries, and charged were prepared for each instrument, each battery used for 8 hours of continuous observation. In addition to this, three walky-talky's were collected for each team to communicate in the field. The most important in this measurement were digital image orthophoto and spatial data (digital parcel map).

3.6 Reference control points

For this research, two GPS reference control points were used from Adigrat city, which underwent processing by the Ethiopian Map Authority (EMA). These points were subsequently

utilized by Adigrat city to create the Adigrat base map. The selection of these two reference points was based on their proximity to the study area, and their coordinates are as follows in Table 3.2 below.

Table 3. 2. Coordinate of reference points

Point	Easting	Northing	Elevation
CP2	552940.885	1572600.372	2515.99
CP1	552470.867	1572554.574	2545.084

3.7 Planimetric coordinate extraction

Feature extraction is a systematic collection of all details appearing on the ground that are also visible on the imagery by digitization into vector form i.e. conversion of data from raster to vector. (Paul et al., 2014). Therefore, coordinates of the selected sample parcel corner (vertex) were extracted from a digital line map (parcel) on Arc GIS, and using the heads-up digitization technique planimetric coordinates of similar parcel corners were extracted from orthophoto and satellite images. This was done manually by creating a point vector layer using Arc GIS. To eliminate error, the sample point vectors were identified at different times independently from orthophoto and satellite images during manual digitization. The point vectors layer created along the parcel corners were digitized following points along the geometry of the feature. The COGO tool in ArcGIS tool can easily calculate the coordinates of the centroid (Adds attributes to store the centroid coordinates) of each parcel using the Calculate Geometry dialog box. Geometry calculations in ArcGIS are planimetric, in other words, they take place in projected space, geodesic space. It can only calculate the area, length, or perimeter of the parcel if the coordinate system being used is a projected coordinate system (Adindan UTM Zone 37N).

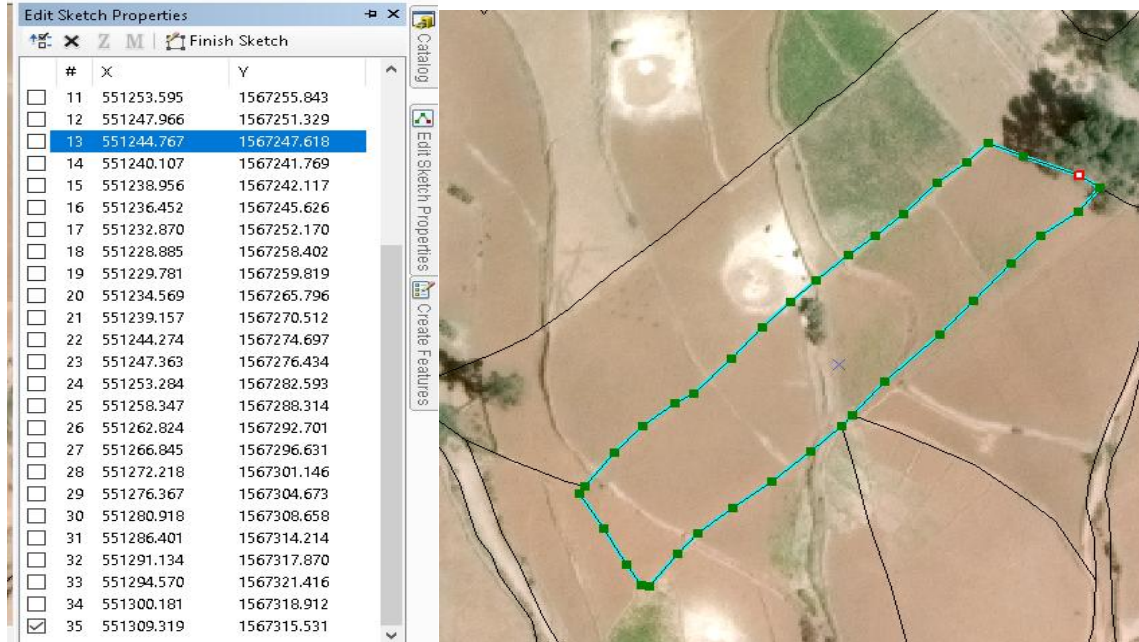


Figure 3. 4. Data extraction in arc GIS

3.8 Accuracy assessment

3.8.1 Fixed boundary accuracy assessment

In the planimetric mapping process, different kinds of features found on the earth according to their standard representation on a map can be extracted in terms of points, lines, and polygons from satellite images, orthophoto, and other spatial source data. Testing the more complex geometry of a polygon requires finding discrete points on the edges of the polygon, such as vertices, which can be correlated to similar points of higher accuracy. If the polygon were a parcel boundary, for instance, one of the checks for spatial accuracy would be to test a corner of the parcel for accuracy. An approach to assess the planimetric accuracy of orthophoto products is based on the use of geometric features (Vieira et al, 2002). Therefore, in this study the planimetric coordinates extracted from the digital parcel map (parcel and point) planimetric accuracy were compared point-wise with total station measurements and direct digitizing from digital orthophoto in terms of x, y, and horizontal root mean squared error (RMSE_x, RMSE_y, and RMSE_H, respectively).

$$RMSE_x = \sqrt{\frac{\sum (X_i(\text{map}) - X_i(\text{surveyed}))^2}{n}}$$

$$\text{RMSE}_y = \sqrt{\frac{\sum(Y_i(\text{map}) - Y_i(\text{surveyed}))^2}{n}}$$

$$\text{RMSE}_H = \sqrt{(\text{RMSE}_x^2 + \text{RMSE}_y^2)}$$

Where: X_i (map), Y_i (map) are the coordinates of the i^{th} point in the digital parcel map

X_i (surveyed), Y_i (surveyed) are coordinates of the i^{th} point in the independent source dataset of higher accuracy and n is the number of check points and i is an integer that ranges from 1 to n

3.8.2 General boundary accuracy assessment

According to Zein (2017). mass registration of land parcels using fit-for-purpose land administration specifies the carta procedure can generally produce a boundary with a positional accuracy of about 2 m for an image resolution of 40/50 cm. In addition to that, when parcel corners were surveyed using photogrammetric technology, their resulting accuracy were calculated to within 5 centimeters to 3 meters, depending on the level of accuracy of the underlying photogrammetric map that was created (McKenna, 2016).

CHAPTER FOUR

Results and Discussion

4.1 Results

The examination of the digital parcel maps were carried out by comparing selected parcel with in-situ total station measurements and field digitization using a digital orthophoto. The digital parcel map was initially demarcated from orthophoto field map sheets and given parcel IDs in the field using a pencil on paper maps at a 1:2000 scale. This was followed by redrawing the parcel boundaries and rewriting the parcel IDs with a pen for enhanced visibility. The process ended with scanning, geo-referencing and digitization. Furthermore, the reference station data utilized for this validation and assessment were procured as secondary information from the Adigrat municipality base map preparation document.

4.1.1. Station orientation result

For this research, two GPS reference control points were used from Adigrat city, which underwent processing by the Ethiopian Map Authority (EMA). These points were subsequently utilized by Adigrat city to create the Adigrat base map.

In this study, the remaining reference points were established by traversing using these two reference stations. The computation of their coordinates was executed using the closed Traverse Bowditch method. These traverse stations were used as a reference for accuracy assessment, and validation of area and perimeter, emphasizing their certainty on precise reference station measurements. The collected and processed data are presented comprehensively in Table 4.1.

Table 4. 1. Traverse computation and coordinate result of reference points

Total distance	21,374.25 Km
Summation of correction in x	0.922m
Summation of correction in y	-0.88m
Linear miss closure error	1.275m
Relative accuracy of the traverse	1:16,774.547=1:17,000

The relative accuracy obtained from Table 4.3 are approximately 1:17,000. Considering the establishment of traverse points using a total station with a 1"-10" accuracy, the acceptable

accuracy range should lie between 1:5,000 and 1:50,000 (Uren et al., 2018). Therefore, as indicated above, the results fall within an acceptable range (Appendix 7).

4.1.2 Digital parcel map horizontal accuracy assessment result

To examine the horizontal accuracy of the digital parcel map, a point-based assessment technique was employed. Each digital spatial data set was independently utilized and compared with data obtained from total station measurements and direct field digitizing using digital orthophoto. The obtained differences in coordinates among the digital parcel map, total station measurements, and direct field digitizing from the digital orthophoto, evaluations were conducted on the same survey points at 30 selected sample points. This process enabled the determination of the planimetric accuracy of the digital parcel map concerning the selected sample points, relative to coordinates computed from the digital parcel map and coordinates obtained from total station measurement and direct field digitizing from the digital orthophoto.

Therefore, the accuracy of the point-based assessment was determined according to the requirements outlined by the American Society for Photogrammetry and Remote Sensing (ASPRS, 2023). The accuracy reporting system specified by ASPRS for horizontal positional accuracy requires the computation and reporting of various metrics. These metrics include residual errors at each checkpoint, maximum error, minimum error, mean error, median error, standard deviation, and Root Mean Square Error (RMSE).

In this study, the horizontal accuracy assessment of the digital parcel map focuses on the parcel corners. Similar sample parcel feature corners were selected for assessing the horizontal accuracy of the digital parcel map (parcel corner) in comparison to total station measurements and field digitization from a digital orthophoto. The horizontal coordinates of the parcel corners were chosen, and parcel vertex coordinates were generated using ArcGIS. These coordinates were then extracted at the vertices of each parcel, with 30 similar vertices selected alongside total station points and field digitization from a digital orthophoto. The horizontal accuracy of the parcel map, when compared to total station measurements, generated the following results.

Table 4. 2. Horizontal accuracy assessment result from total station measurement

Error type	x	y
Sum of squares	40.928	45.464
Mean	1.364	1.515
RMSE _{x,y(m)}	1.168	1.231
RMSE _{H(m)}	1.697	

All coordinate values in this study were computed using the Root Mean Square Error (RMSE) concerning the spatial data coordinate results at the same point. ASPRS, 20203 standard recommend calculating the RMSE based on the differences between x and y separately. Consequently, the RMSE for each sample feature is independently computed. The results of these computations are presented above (table 4.3). Based on the table 4.3 results, the RMSE for the difference between the spatial data coordinates of all sample features and in-situ total station measurements at similar checkpoints in the x and y directions were obtained at 1.168 m and 1.231 m, respectively, and the horizontal linear RMSE in the radial direction that includes both x- and y- coordinate errors is obtained 1.697m (Appendix 1).

Furthermore, the horizontal accuracy of digital parcel maps is evaluated on parcel corners derived from spatial data and directly digitized on digital orthophotos. The planimetric accuracy (x, y) was evaluated using coordinates obtained from 30 selected sample parcel corners independently extracted from the digital orthophoto and spatial parcel maps. Consequently, 30 sample planimetric coordinates (vertices) were derived from the digital parcel map using GIS extraction techniques. Additionally, another set of 30 vertices was collected using a digital orthophoto in the field. All coordinate values in this study were computed concerning spatial data coordinate results at the same point. The results of this computation are presented below in Table 4.3.

Table 4. 3. Horizontal accuracy assessment result from digital orthophoto

Error type	Along x	Along y
Sum of squares	44.099	35.887
Mean	1.470	1.196
RMSE _{x,y} (m)	1.212	1.094
RMSE _H (m)	1.633	

Based on the above-mentioned findings, the Root Mean Square Error (RMSE) for the difference between the spatial data coordinates of all sample features and in-situ digitizing coordinates of corresponding checkpoints in the x and y directions were obtained 1.212m and 1.094m respectively , and the horizontal linear RMSE in the radial direction that includes both x- and y-coordinate errors is obtained 1.633m (Appendix 2).

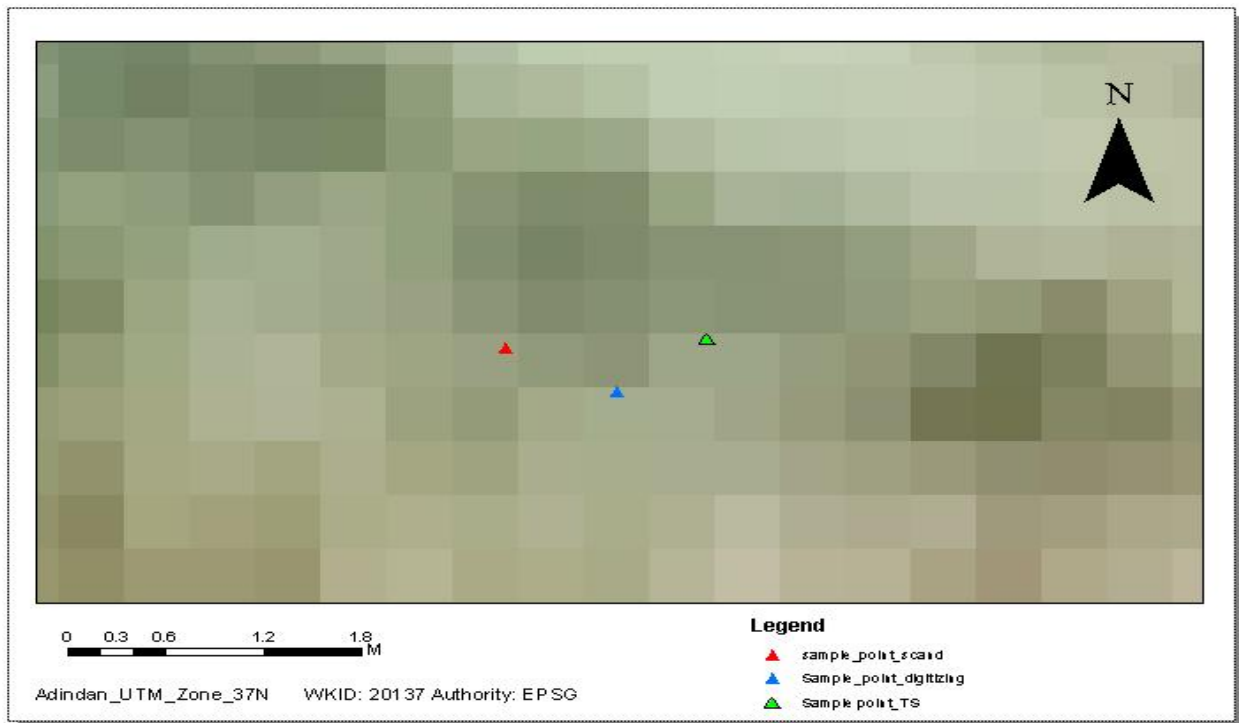


Figure 4. 1 shows the point wise difference in accuracy assessment

4.1.3 Validation of digital Parcel area and perimeter assessment results

4.1.3.1 Validation of digital Parcel area

This study was aimed to verify the area of digital parcel maps using field demarcation based on digital orthophotos and total station measurements. Table 4.6 shows the data collected in the field, including the number of data points for each verification method. The study covers 70 parcels measured by total station and 60 parcels demarcated directly in the field using digital orthophotos.

Results from field demarcation using digital orthophotos on-site yielded the following outcomes. In the area range of 0.0258ha to 0.1002ha, a percentage difference of 9.69 % to 3.69% was observed, while for the range of 0.1002ha to 0.810ha, the percentage difference ranged from 3.69 % to 1%,. as well as the summation difference in hectare is 0.110ha and mean error is 0.002Ha (Appendix 3).

Furthermore, total station verification of the area was conducted. The survey commenced with the utilization of the relative positioning technique through the Leica Total Station. In this study, 70 parcels were collected as polygons in the field to validate parcel areas and assess the accuracy of corner parcels.

Table 4. 5. Number of parcels collected utilizing a total station.

No	Data collection method	Sample type	No. of feature collected	Remark
			40	In Flat area
1	Data collection by using	Parcel	15	In Mountain areas
	total station		15	In Irrigation

From this survey, the difference between the spatial data areas of all sample parcels and in-situ survey areas of similar parcels were collected. Sample results of this computation presented below on table 4.6.

Table 4. 6 comparison of area with the total station measurement

Parcel_ID	area_field (A)	area_spatial (B)	area difference (B-A)	Area difference %
1566	0.158	0.163	0.005	2.768
2792	0.123	0.119	-0.004	-3.361
2793	0.141	0.146	0.005	3.425
6382	0.140	0.146	0.006	4.178
9289	0.280	0.275	-0.005	-1.710
9290	0.086	0.084	-0.002	-2.616
9291	0.309	0.305	-0.004	-1.213
9293	0.270	0.276	0.006	2.138
9306	0.265	0.255	-0.010	-3.842
9321	0.235	0.251	0.016	6.218
9326	0.117	0.124	0.006	4.939
9333	0.111	0.102	-0.009	-8.538
11221	0.106	0.102	-0.005	-4.433
1787	1.002	1.001	-0.001	-0.070
6198	1.355	1.328	-0.027	-2.026
6525	1.527	1.525	-0.002	-0.138
10827	2.183	2.204	0.021	0.935
4197	2.503	2.492	-0.011	-0.446

Based on the above Table 4.6 results, the percentage difference in area between the spatial data areas of all sample features and the in-situ total station survey areas of corresponding parcels was calculated. As indicated in the table above, the area validation for flat areas 0.018ha, 0.106ha, and 2.5ha the area difference obtained -7.14%, -4.43%, and -0.45%, respectively. Furthermore, in an irrigation area of 0.014ha, the difference was 7.69%, while for 0.05ha, it was -4% was obtained. In mountainous terrain, the variations were 7.84% for 0.055ha and 3.1% for 0.499ha (Appendix 4).

The area of the spatial data (digital parcel map) was calculated using ARC GIS, where the digital parcel map (parcel boundary) was compared with total station survey measurements conducted on-site and direct field digitizing from orthophoto. Consequently, a statistically significant difference exists for each parcel area when comparing the outcomes from all methods. The table below illustrates an example of differences in the validation process and differences in results, specifically focusing on the examination of data obtained from digital orthophoto and the relevant data source.

Table 4. 7 Presents percentage difference in the area between DPM and DO

Parcel_ID	Area_data	Area_field	Difference	difference in area %
1566	0.163	0.1691	-0.0065	0.0163
2792	0.119	0.1134	0.0056	0.0119
2793	0.146	0.1414	0.0049	0.0146
6382	0.146	0.1392	0.0069	0.0146
9289	0.275	0.2791	-0.0041	0.0275
9290	0.084	0.0884	-0.0048	0.0084
9291	0.305	0.3005	0.0045	0.0305
9293	0.276	0.2845	-0.0089	0.0276
9306	0.256	0.2537	0.0018	0.0256
9321	0.251	0.2404	0.0101	0.0251
9326	0.123	0.1176	0.0057	0.0123
9333	0.102	0.1042	-0.0026	0.0102

The figure below illustrates the percentage difference in the area of selected parcels computed from the digital Orthophoto and digital parcel map. Variations among the areas were verified concerning digital Orthophoto and spatial data sources. The variation in parcel areas related to spatial data sources shows a slightly smaller difference between spatial data and on-screen digitizing results. According to the findings, the difference increases as the parcel area decreases. In other words, accuracy in area measurement is better for larger parcels than for smaller ones.

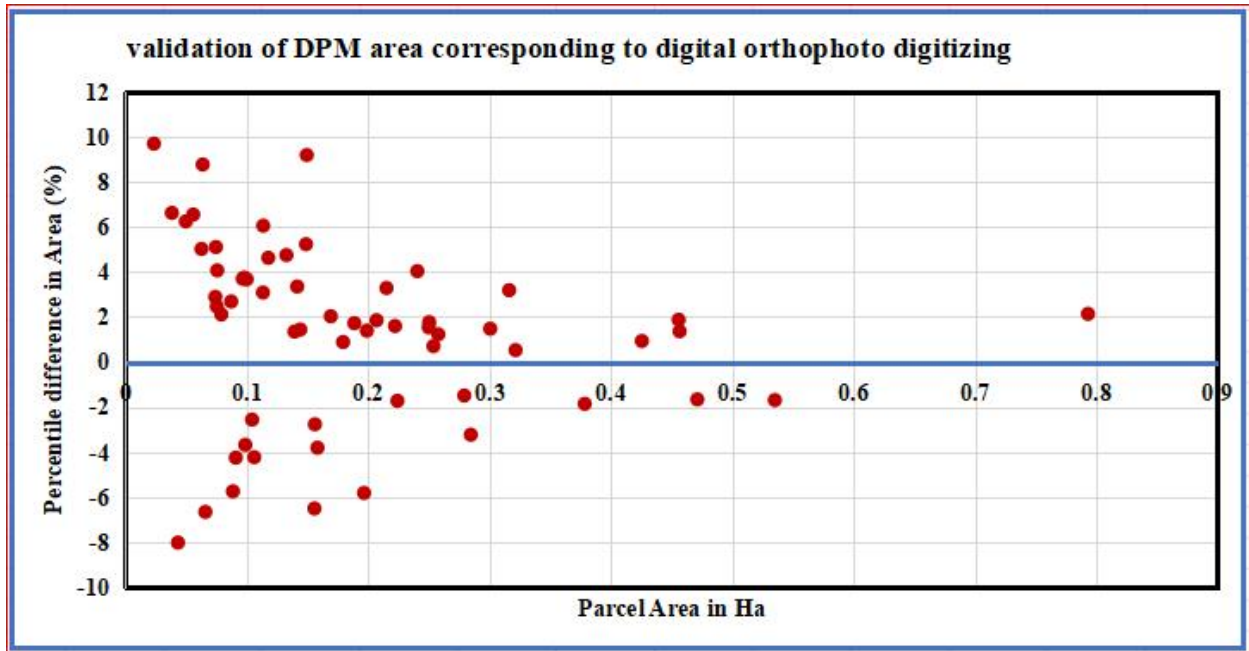


Figure 4. 2 Relationship between the area difference corresponding to DO

In addition to validating the parcel area through digital orthophoto demarcation in the field, the total station was also used to validate the digital parcel map. The validation was conducted across various configurations, including flat areas (measuring both small and large areas), irrigation areas, and mountainous areas. The subsequent sample results were also determined.

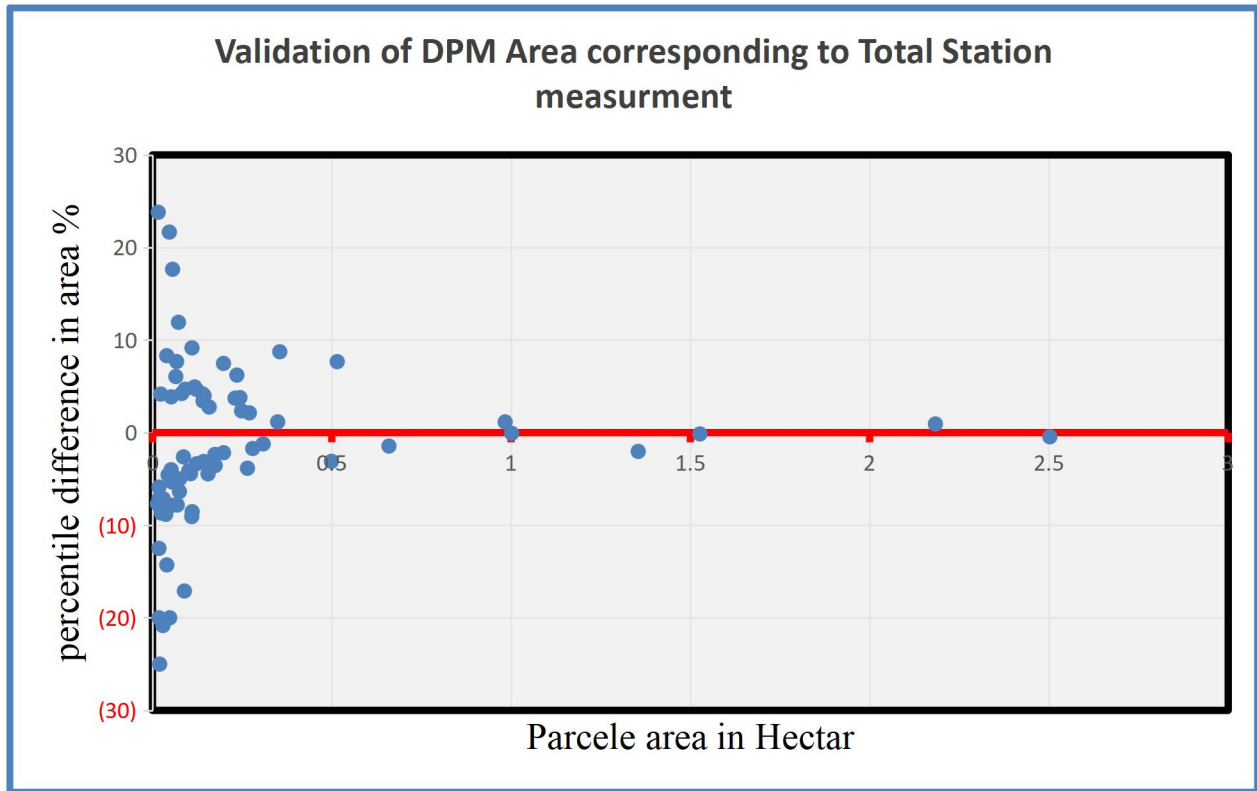


Figure 4. 3 Correlation between the difference data obtained from total station

Appendix 3 reveals that out of 60 parcels collected in the field using digital orthophoto, the area of all 60 parcels falls within the acceptable range, indicating 100% compliance with the acceptable range for the digital parcel map.

In general, the results reveal an inversely proportional relationship between area and variation difference. The validation of the results indicates that as the parcel area decreases, the difference increases, and as the parcel area increases, the difference decreases. Therefore, there is a significant difference in errors for small parcels. Generally, the following results are obtained from both total station and digital orthophoto measurement comparing to digital parcel map as follows in table 4.8.

Table 4. 8 show the number of parcel and accuracy standard of the sample area

Hectare	Total no. Of					out of standard
	Parcel	Class I	Class II	Class III		
≤ 0.1	51	21	20	2	8	
0.1- 0.5	69	60	9	-	-	
≥ 0.5	10	9	0	1	-	

From Table 4.8 in the study, 51 parcels were collected, and their areas were ≤ 0.1 hectares. Out of these, 8 parcels did not meet the standard. Therefore, in this kebele, there are approximately 2822 parcels with an area of ≤ 0.1 hectares. Comparing this to the total number of parcels in the kebele and the total number of parcels measured in this study, 8.16% (443 parcels) of the total parcels fall outside the general boundary standards.

4.1.3.2 Validation of Parcel Perimeter assessment result

This study validates the perimeters of digital parcel maps using a total station and digital orthophoto. Rural land parcels, often irregular in shape, may not be accurately represented by orthophoto maps, particularly in terms of small curves and straight lines. During the drawing process, some edges may become unclear, complicating the task of marking points. Similarly, invisible boundaries can emerge during demarcation, presenting challenges in accurately marking each point. The shape lengths extracted from selected digital parcel maps were compared to similar parcel measurement in-situ total station measurements and the digitization from the digital orthophoto. The perimeters on the digital parcel map, for 18 selected parcels, were compared. The results of the perimeter errors, in relation to the total station survey data and spatial data, are presented in Table 4.11 below.

Table 4. 9. Summation, mean, and percentile error in perimeter values.

Parcel_ID	Spatial perimeter (SP)	(SP-TS (Total station)) %	(SP-DO (digital orthophoto)) %
11221	135.759	3.60	-7.41
9333	140.828	-3.64	-4.44
9293	242.528	0.188	-1.203
9294	270.547	0.477	0.140
Sum		18.639	16.367
Mean		1.036	0.909

The mean distance error for 18 parcels was determined through measurements conducted with both a total station and digital orthophoto in the field. The total station measurement resulted in a summation difference of 18.639m for the digital parcel map perimeter, while the digital

orthophoto measurement yielded a difference of 16.367m. The corresponding mean errors for these differences were calculated as 1.036 m and 0.909m, respectively (Appendix 5).

The results of this study indicate that the summation and mean difference in perimeter between the total station survey and digital parcel map are 18.639m and 1.036m, respectively. Additionally, the difference in perimeters between digital parcel maps and digital orthophoto is 16.367m and 0.909m, respectively. Moreover, Appendix 5 reveals that the results of the study, when validating using the total station, show a validation error difference ranging from 3.60 % in the 135.759 m perimeter to + 0.48 % in the 270.547m perimeter. Similarly, in the same parcel perimeter, Appendix E presents that the validation using digital orthophoto has a validation error difference ranging from -7.41% to + 0.14 %.

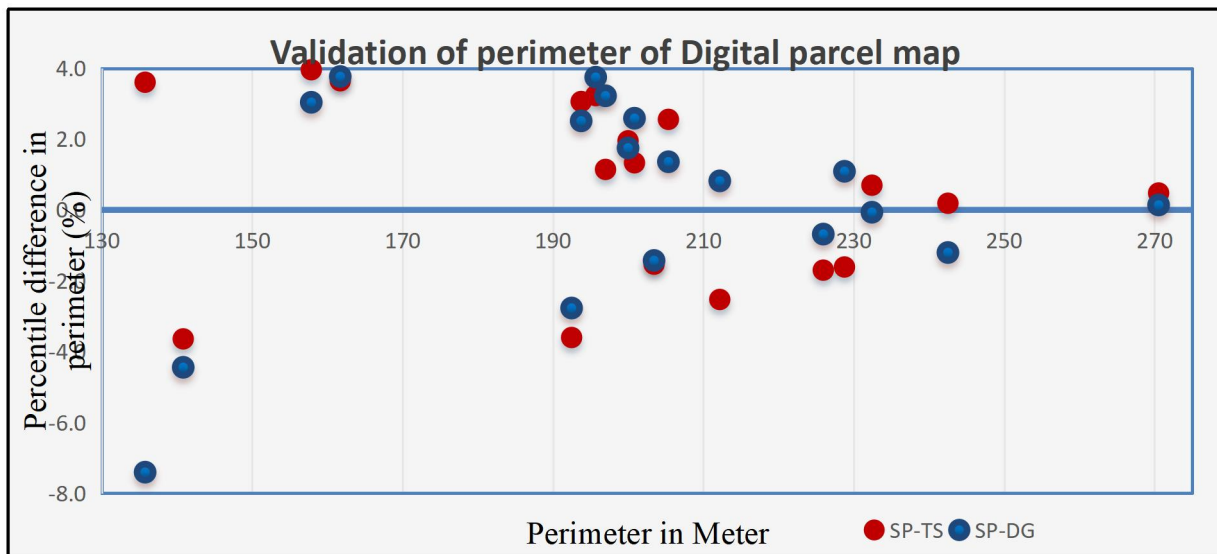


Figure 4. 4 shows the correlation among the perimeter

Therefore, based on the above results, indicates that when the perimeter of the parcel increased the accuracy of the parcel is better when the parcel perimeter is small the accuracy of the digital parcel map becomes large. The data obtained from a digital orthophoto on-site compared to the demarcation of the parcel from the field sheet map. When compared with the total station survey, almost similar values will be obtained.

4.2. Discussion

The digital parcel map utilized in this study was prepared by LIFT (Land Information for Transformation) in 2018. The map was prepared from an orthophoto, having a 40 cm resolution. This thesis aimed to assess the horizontal accuracy and validity of the digital parcel map created by Orthophoto for securing cadastral maps in Kebelle Guahgot. For this study Selected samples from the digital spatial data (digital parcel map) sources were used to extract coordinates, areas, and perimeters to compare with the measurements from total station surveys and digitized data from digital Orthophoto. For this study, the most challenging and tedious work in the process was selecting and identifying checkpoints or parcel corners with defined landmarks and visible corners in the orthophoto.

According to ZEIN (2017), the map used for the SLLC program was crafted from satellite images and aerial photography, employing 40 cm resolution orthorectified aerial photographs captured and processed by the Ethiopian Mapping Agency (EMA). Surveyors marked boundaries identified on the ground onto the orthophoto image and assigned a unique parcel identification number to each land parcel. During fieldwork, parcel boundaries were initially drawn on orthophotos using pencils. The para-surveyor then drew the boundary lines on the field map sheet after confirmation by the owner of the subject parcel and neighboring holders, facilitated by the Land Administration & Use Committee member. The orthophoto maps are scanned, georeferenced, and then digitized on-office when surveyors manually mark the parcel borders. The legal tenure rights of landholders and claimants are documented as attributes in the land administration system. After confirming parcel boundaries and registration information during open data presentations, the final step involves issuing certificates or title documents. This occurs in the field, in the presence of neighbors and members of the locally nominated Kebelle Land Administration Committee.

The total station was used to conduct traverse surveys, distributing temporary traverse stations across the entire study area for data collection. Additionally, measurements were taken at checkpoints using relative positioning techniques to assess validation, covering both area and perimeter.

To evaluate the horizontal accuracy and validation of the digital parcel map, both total station measurements and direct field digitization from the digital orthophoto were employed. During

field demarcation on the digital orthophoto, visible parcel boundaries (those with berms) were deliberately selected to minimize measurement errors. For accuracy assessment, similar sample points were chosen from the digital parcel map, digital orthophoto, and the ground. These points were then compared with total station surveys and digital orthophotos.

4.2.1. Digital parcel map horizontal accuracy assessment

To assess horizontal accuracy, a point-based accuracy assessment method was employed. In this method, planimetric coordinates extracted from selected samples from digital spatial data sources were compared with total station measurement collected in the field and direct field demarcation using digital orthophoto coordinates from similar samples. The Root Mean Square Error (RMSE) for each data-set was then computed. The calculation of RMSE, as suggested by ASPRS standards, was applied independently to each sample feature. Additionally, $RMSE_H$ were computed. Based on measurement the horizontal linear RMSE in the radial direction that includes both x- and y- coordinate errors is obtained 1.697m and 1.633 using total station and digital orthophoto respectively.

According to Jack McKenna, (2016), in general boundary demarcation the boundary maximum error can be inward or outward by 3 meters off-set from the true boundary. Therefore, the SLLC program is within the acceptable range compared to the general boundary principles.

According to Zein (2017), also specifies that the carta-procedure can generally produce a boundary with a positional accuracy of about 2 m for an image resolution of 40/50 cm. Based on this study the accuracy of the digital parcel map is within acceptable range.

As to the American Society for Photogrammetry and Remote Sensing (ASPRS,1990) outlined, for the production of large-scale maps at a 1:2000 scale planimetric accuracy falling within Class I (0.5m), Class II (1.0m), and Class III (1.5m). But the horizontal linear RMSE in the radial direction that includes both x- and y- coordinate errors is obtained 1.697m and 1.633 using total station and digital orthophoto respectively. The acquired data, however, falls short of meeting these standards, indicating its in-applicability for the production of large-scale planimetric maps at a 1:2000 scale.

4.2.2. Validation of parcel area and perimeter

4.2.2.1 Validation of parcel area

The area of the spatial data (digital parcel map) was calculated using ARC GIS, where the digital parcel map (parcel boundary) was compared with total station survey measurements conducted

on-site and direct field digitizing from orthophoto. Consequently, a statistically significant difference exists for each parcel area when comparing the outcomes from all methods.

According to McKenna's (2016), comparison of area should be within the range of 83%-92% for a scale map accuracy of 1:2000, corresponding to actual areas of 0.1- 0.5 hectares, respectively. Based on this the SLLC map areas are within the acceptable range for parcel area ≥ 0.1 and not satisfied for ≤ 0.1 hectare.

Similarly, from the comparison b/n total station and digital parcel map indicates that out of 70 parcels collected using total station, the area of 62 parcels falls within the acceptable range, while 8 parcel (11.43%) parcels exhibit an error exceeding 17%.

4.2.2.2 perimeter assessment

The purpose of the perimeter assessment is to evaluate the accuracy of digital parcel map comparing to total station and digital orthophoto demarcation . The aim is to quantify differences between the observed shapes perimeter in the dataset and the true or expected shapes, ensuring the reliability and quality of spatial data for applications such as land administration, mapping, and geographic information systems (GIS). For this study, 18 parcels were randomly selected, and tie line lengths were measured from the extracted parcels. Corresponding field measurements were retrieved from the existing data recorded by the cadastral office using Total Station observations. The minimal difference between these two measurements suggests that both methods of accuracy-checking techniques affirm the accuracy of the cadastral data extraction process.

The result reveals that , when validating using the total station, show a validation error difference ranging from 3.60 % in the 135.759 m perimeter to + 0.48 % in the 270.547m perimeter. Similarly, in the same parcel perimeter, using digital orthophoto has a validation error difference ranging from -7.41% to + 0.14 %. Based on this findings , the perimeter of parcel accuracy increased when the parcel perimeter increased and the the perimeter of parcel accuracy decreased when the parcel boundary is small.

CHAPTER FIVE

Conclusions and Recommendations

5.1. Conclusions

The study aims to assess the horizontal accuracy and validation of a digital parcel map derived from a hard copy orthophoto. This map plays a crucial role in securing cadastral maps for rural land administration during second-level land certification in Kebelle Guahgot. To assess the accuracy of vertex parcels, the American Society for Photogrammetry and Remote Sensing (ASPRS) mapping accuracy standards are applied. The root mean square error (RMSE) is computed for the horizontal accuracy assessment point dataset. This assessment, conducted using a point-based method, focuses on RMSE in the x and y directions from field survey checkpoints and derived coordinates from digital parcel map. In addition to accuracy assessment, validation of the area and perimeter of the digital parcel map, the general boundary standards were used, and a comparison of area and perimeter was performed among the field measurement and digital parcel map data.

The horizontal accuracy of digital parcel maps obtained from second level land certification at scale of 1:2000 is not meet for fixed boundary standards but it is within acceptable range according to general boundary standards.

In addition to that, Based on the findings presented in demarcation using printed orthophoto field map sheets (hard copy Orthophoto) at scale of 1:2000 is giving good results for large parcels (≥ 0.1 ha), while achieving good parcel result for small parcels (≤ 0.1 hectare) is challenging.

In general, utilizing a printed Orthophoto field map sheet for the demarcation process is not the optimal method to achieve more accurate data and the result shows that the data collected using Digital Orthophoto gives better accuracy than Orthophoto field map sheet results. Therefore, using digital Orthophoto for second-level land certification provides better accuracy results.

5.2. Recommendation

Spatial data is fundamental for any mapping activities, such as engineering, land administration, and planning applications, especially those that need high accuracy and are used for decision-making processes. They should be uniform and fulfill national and international accuracy standards. The accuracy of spatial data that are used for similar applications should be comparable or within the acceptable error range based on the standard. In this study, the Orthophoto is used for cadastral application. However, based on the result obtained from this study, the printed hard copy Orthophoto is not as accurate as the digital Orthophoto for preparing large-scale cadastral applications and the production of Rural cadastral maps. Therefore, it is recommended that the Office of Environmental Protection and Rural Land Administration use this digital Orthophoto for producing large-scale maps.

Generally, to practice healthy land administration and management, and to fulfill all issues related to the sound sustainable use of land. I would like to recommend that:

- Demarcation using printed orthophoto field map sheet should be replaced by direct field demarcation using digital orthophoto. The digital image provides the advantage of being viewable at various scales, and ensuring clearer visibility compared to hard copy or printed field map sheets. Additionally, this method eliminates the necessity for scanning, Geo-referencing and is not constrained by the limitations of pencil and pen width.
- The federal government, regional governments, and non-governmental organizations should carefully consider transitioning from the current demarcation methods to digital digitizing techniques to improve rural land demarcation accuracy.
- Future studies should focus on improving the accuracy of small parcels by utilizing GNSS measurements and different software packages for evaluating digital parcel maps used in the second-level land demarcation process.

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Appendices

Appendix 1. Digital parcel map horizontal accuracy assessment result from total station

Id	Data from spatial data(A)		Data from total station(B)		Difference (A-B)		squared	
	X coordinate	Y coordinate	X coordinate	Y coordinate	Δx	Δy	$(\Delta x)^2$	$(\Delta y)^2$
1	551353.554	1565304.990	551353.900	1565304.366	-0.346	0.624	0.120	0.389
2	551379.593	1565184.254	551381.200	1565183.545	-1.607	0.709	2.582	0.503
3	551359.502	1565178.884	551359.500	1565177.906	0.002	0.978	0.000	0.956
4	552122.608	1564339.445	552124.100	1564338.168	-1.492	1.277	2.227	1.631
5	553030.245	1563742.776	553031.400	1563741.866	-1.155	0.910	1.334	0.828
6	553019.335	1563632.751	553020.700	1563632.077	-1.365	0.674	1.864	0.454
7	550103.173	1563677.607	550102.700	1563678.858	0.473	-1.251	0.224	1.565
8	550132.563	1563627.072	550133.800	1563626.843	-1.237	0.229	1.529	0.052
9	552778.492	1564412.469	552779.700	1564413.552	-1.208	-1.083	1.460	1.173
10	551508.147	1567727.536	551506.600	1567729.187	1.547	-1.651	2.393	2.726
11	550565.539	1566442.060	550564.900	1566439.996	0.639	2.064	0.408	4.260
12	552363.363	1568343.199	552364.000	1568345.281	-0.637	-2.082	0.406	4.335
13	552134.355	1568295.098	552132.500	1568292.739	1.855	2.359	3.442	5.565
14	550549.382	1563510.042	550550.000	1563511.111	-0.618	-1.069	0.382	1.143
15	550608.970	1563409.970	550609.500	1563409.155	-0.530	0.815	0.281	0.664
16	550576.272	1563423.756	550574.500	1563423.960	1.772	-0.204	3.141	0.042
17	550528.538	1563331.210	550528.200	1563330.613	0.338	0.597	0.114	0.356
18	550417.008	1563343.495	550416.800	1563343.895	0.208	-0.400	0.043	0.160
19	551088.611	1565434.734	551089.800	1565434.117	-1.189	0.617	1.415	0.381
20	551131.659	1565440.876	551129.700	1565439.269	1.959	1.607	3.838	2.582
21	551159.563	1565502.244	551158.900	1565500.933	0.663	1.311	0.439	1.719
22	552406.563	1568388.952	552406.600	1568390.528	-0.037	-1.576	0.001	2.484
23	551576.895	1567835.441	551578.200	1567835.646	-1.305	-0.205	1.703	0.042
24	551969.221	1565777.891	551967.300	1565780.417	1.921	-2.526	3.690	6.381
25	552790.698	1564284.384	552791.800	1564285.600	-1.102	-1.216	1.215	1.479
26	551921.474	1566038.544	551920.600	1566037.576	0.873	0.968	0.763	0.937
27	550569.590	1566254.357	550568.400	1566252.906	1.190	1.451	1.417	2.105
28	550442.435	1566206.004	550441.234	1566205.319	1.201	0.685	1.442	0.469
29	551087.081	1565101.023	551086.100	1565101.233	0.981	-0.210	0.962	0.044
30	552680.747	1564300.443	552679.300	1564300.639	1.447	-0.196	2.093	0.038
Sum of squares							40.928	45.464
Mean							1.364	1.515
RMSE _{X,Y} (M)							1.168	1.231
RMSE _H (M)							1.697	

Appendix 2. Digital parcel horizontal accuracy assessment result from Digital orthophoto

Id	Digitizing orthophoto		Data from spatial data		Difference (A-B)		Squired	
	x coordinate	Y coordinate	X coordinate	Y coordinate	ΔX	Δy	$(\Delta x)^2$	$(\Delta y)^2$
1	551354.886	1565304.959	551353.5539	1565304.99	-1.332	0.031	1.775	0.001
2	551380.844	1565184.362	551379.5932	1565184.254	-1.251	-0.108	1.566	0.012
3	551359.617	1565178.366	551359.5017	1565178.884	-0.115	0.518	0.013	0.268
4	552123.876	1564338.491	552122.6076	1564339.445	-1.269	0.954	1.609	0.910
5	553031.947	1563742.320	553030.2451	1563742.776	-1.702	0.456	2.896	0.208
6	553021.028	1563632.033	553019.3347	1563632.751	-1.693	0.718	2.867	0.516
7	550104.623	1563677.818	550103.1731	1563677.607	-1.450	-0.211	2.103	0.045
8	550131.514	1563625.556	550132.5633	1563627.072	1.049	1.516	1.100	2.298
9	552779.894	1564414.938	552778.4915	1564412.469	-1.402	-2.469	1.966	6.096
10	551507.250	1567728.887	551508.1468	1567727.536	0.897	-1.351	0.805	1.825
11	550564.995	1566440.275	550565.5386	1566442.06	0.543	1.785	0.295	3.186
12	552363.932	1568344.742	552363.3625	1568343.199	-0.570	-1.543	0.325	2.381
13	552132.656	1568294.212	552134.3552	1568295.098	1.699	0.886	2.888	0.785
14	550551.156	1563510.297	550549.3821	1563510.042	-1.774	-0.255	3.148	0.065
15	550609.105	1563409.278	550608.97	1563409.97	-0.135	0.692	0.018	0.479
16	550575.315	1563423.983	550576.2724	1563423.756	0.957	-0.227	0.916	0.052
17	550528.509	1563329.499	550528.5376	1563331.21	0.028	1.711	0.001	2.928
18	550416.524	1563344.316	550417.0076	1563343.495	0.483	-0.821	0.234	0.674
19	551089.287	1565433.728	551088.6106	1565434.734	-0.676	1.006	0.457	1.012
20	551130.260	1565439.500	551131.659	1565440.876	1.399	1.376	1.959	1.893
21	551159.081	1565500.997	551159.5629	1565502.244	0.482	1.247	0.233	1.555
22	552406.011	1568390.158	552406.5627	1568388.952	0.552	-1.206	0.305	1.454
23	551577.785	1567834.385	551576.8949	1567835.441	-0.890	1.056	0.792	1.115
24	551967.740	1565779.984	551969.2209	1565777.891	1.481	-2.093	2.194	4.381
25	552792.525	1564285.795	552790.6979	1564284.384	-1.827	-1.411	3.339	1.991
26	551920.399	1566038.207	551921.4735	1566038.544	1.074	0.337	1.154	0.114
27	550568.350	1566252.696	550569.5904	1566254.357	1.241	1.661	1.539	2.759
28	550440.451	1566206.906	550442.4347	1566206.004	1.984	-0.902	3.936	0.814
29	551086.150	1565100.927	551087.0807	1565101.023	0.931	0.096	0.867	0.009
30	552679.073	1564300.458	552680.7468	1564300.443	1.674	-0.015	2.801	0.000
Sum of squaers							44.099	39.825
Mean							1.470	1.327
RMSE _{X,Y} (M)							1.212	1.152
RMSE _H (M)							1.673	

Appendix 3. Validation of digital Parcel area from direct Digital orthophoto measurement

Parcel_ID	Area_spatial	Area_field	difference	difference in %
97	0.1644	0.1493	0.0151	9.1849
99	0.2256	0.222	0.0036	1.5957
102	0.1002	0.0965	0.0037	3.6926
138	0.2202	0.224	-0.0038	-1.7257
1511	0.0408	0.0381	0.0027	6.6176
1516	0.1918	0.1885	0.0033	1.7205
1521	0.2537	0.2498	0.0039	1.5372
1566	0.163	0.1691	-0.0061	-3.7423
1633	0.1857	0.1965	-0.0108	-5.8158
1634	0.2016	0.1988	0.0028	1.3889
1636	0.0871	0.0908	-0.0037	-4.2480
2239	0.5262	0.5351	-0.0089	-1.6914
2240	0.0399	0.0431	-0.0032	-8.0201
2244	0.0806	0.0789	0.0017	2.1092
2248	0.0658	0.0625	0.0033	5.0152
2251	0.1808	0.1792	0.0016	0.8850
2252	0.1518	0.156	-0.0042	-2.7668
2254	0.4295	0.4255	0.004	0.9313
2389	0.4629	0.4566	0.0063	1.3610
2392	0.077	0.0751	0.0019	2.4675
2474	0.2223	0.215	0.0073	3.2839
2729	0.2547	0.2502	0.0045	1.7668
2730	0.146	0.1439	0.0021	1.4384
2731	0.1168	0.1132	0.0036	3.0822
2791	0.2107	0.2068	0.0039	1.8510
2792	0.119	0.1134	0.0056	4.7059
2793	0.146	0.1414	0.0046	3.1507
2807	0.0761	0.0739	0.0022	2.8909
2808	0.0784	0.0744	0.004	5.1020
2847	0.1036	0.0998	0.0038	3.6680

2852	0.0529	0.0496	0.0033	6.2382
4461	0.1569	0.1487	0.0082	5.2263
6268	0.3715	0.3784	-0.0069	-1.8573
6283	0.2609	0.2577	0.0032	1.2265
6284	0.0696	0.0635	0.0061	8.7644
6286	0.1461	0.1556	-0.0095	-6.5024
6382	0.146	0.1392	0.0068	4.6575
7553	0.8105	0.7932	0.0173	2.1345
7554	0.0596	0.0557	0.0039	6.5436
7555	0.3265	0.3161	0.0104	3.1853
7744	0.0616	0.0657	-0.0041	-6.6558
8513	0.0894	0.087	0.0024	2.6846
8514	0.0787	0.0755	0.0032	4.0661
9275	0.3231	0.3214	0.0017	0.5262
9289	0.275	0.2791	-0.0041	-1.4909
9290	0.0836	0.0884	-0.0048	-5.7416
9291	0.305	0.3005	0.0045	1.4754
9293	0.2756	0.2845	-0.0089	-3.2293
9294	0.4635	0.4712	-0.0077	-1.6613
9295	0.1015	0.0977	0.0038	3.7438
9306	0.2555	0.2537	0.0018	0.7045
9321	0.2505	0.2404	0.0101	4.0319
9326	0.1233	0.1176	0.0057	4.6229
9327	0.0951	0.0986	-0.0035	-3.6803
9333	0.1016	0.1042	-0.0026	-2.5591
9861	0.0258	0.0233	0.0025	9.6899
10633	0.4645	0.4558	0.0087	1.8730
10635	0.1391	0.1325	0.0066	4.7448
10872	0.1523	0.1581	-0.0058	-3.8083
11221	0.1017	0.106	-0.0043	-4.2281
			0.103	
			0.002	

Appendix 4. Validation of digital parcel area from total station measurement

Parcel_ID	area_field (A)	area_spati (B)	area difference (B-A)	Area difference %
11482	0.014	0.013	-0.001	-7.692
11490	0.016	0.021	0.005	23.810
9691	0.018	0.017	-0.001	-5.882
9695	0.018	0.015	-0.003	-20.000
9696	0.018	0.016	-0.002	-12.500
11182	0.018	0.017	-0.001	-7.143
9692	0.020	0.016	-0.004	-25.000
9694	0.023	0.024	0.001	4.167
9693	0.025	0.023	-0.002	-8.696
11501	0.026	0.024	-0.002	-8.333
11497	0.029	0.024	-0.005	-20.833
11503	0.030	0.028	-0.002	-7.143
11480	0.037	0.034	-0.003	-8.824
6385	0.040	0.043	0.004	8.314
11483	0.040	0.035	-0.005	-14.286
1524	0.044	0.042	-0.002	-4.567
11479	0.047	0.060	0.013	21.667
11478	0.048	0.040	-0.008	-20.000
11477	0.052	0.050	-0.002	-4.000
6383	0.052	0.054	0.002	3.867
10543	0.055	0.051	-0.004	-7.843
1527	0.055	0.053	-0.003	-5.333
7532	0.056	0.068	0.012	17.647
6337	0.065	0.069	0.004	6.061
10594	0.067	0.073	0.006	7.682
10544	0.069	0.064	-0.005	-7.813
11181	0.072	0.082	0.010	11.922
6384	0.075	0.071	-0.005	-6.365
6356	0.076	0.072	-0.004	-4.993

6386	0.082	0.085	0.004	4.230
9290	0.086	0.084	-0.002	-2.616
7531	0.089	0.076	-0.013	-17.105
6355	0.091	0.096	0.005	4.692
10542	0.101	0.097	-0.004	-4.124
11221	0.106	0.102	-0.005	-4.433
11222	0.110	0.100	-0.009	-9.064
6381	0.110	0.121	0.011	9.158
9333	0.111	0.102	-0.009	-8.538
9326	0.117	0.124	0.006	4.939
7529	0.122	0.128	0.006	4.688
2792	0.123	0.119	-0.004	-3.361
6382	0.140	0.146	0.006	4.178
2793	0.141	0.146	0.005	3.425
1501	0.143	0.138	-0.004	-3.111
7525	0.144	0.150	0.006	4.000
10592	0.155	0.148	-0.007	-4.450
1566	0.158	0.163	0.005	2.768
10545	0.174	0.170	-0.004	-2.353
7521	0.175	0.169	-0.006	-3.550
10546	0.198	0.214	0.016	7.477
1516	0.198	0.194	-0.004	-2.166
11216	0.230	0.239	0.009	3.722
9321	0.235	0.251	0.016	6.218
1521	0.244	0.254	0.010	3.787
1522	0.248	0.254	0.006	2.358
9306	0.265	0.255	-0.010	-3.842
9293	0.270	0.276	0.006	2.138
9289	0.280	0.275	-0.005	-1.710
9291	0.309	0.305	-0.004	-1.213
1503	0.349	0.353	0.004	1.161
2796	0.355	0.389	0.034	8.740
2576	0.499	0.484	-0.015	-3.099

6254	0.515	0.558	0.043	7.670
11308	0.659	0.650	-0.009	-1.446
1512	0.984	0.995	0.012	1.156
1787	1.002	1.001	-0.001	-0.070
6198	1.355	1.328	-0.027	-2.026
6525	1.527	1.525	-0.002	-0.138
10827	2.183	2.204	0.021	0.935
4197	2.503	2.492	-0.011	-0.446
Sum			0.067	
mean			0.001	

Appendix 5. Validation of perimeter assessment result

Parcel_	digitizing perimeter (DG)	spatial perimeter (SP)	Total station perimeter (TS)	SP-TS	SP-DG	(SP-TS) %	(SP-DG) %
11221	145.812	135.759	130.865	4.894	-10.053	3.605	-7.405
9333	147.087	140.828	145.957	-5.129	-6.259	-3.642	-4.444
9290	153.062	157.858	151.611	6.247	4.796	3.957	3.038
6382	155.621	161.711	155.815	5.896	6.09	3.646	3.766
9327	197.813	192.48	199.414	-6.934	-5.333	-3.602	-2.771
1566	188.88	193.75	187.821	5.929	4.87	3.060	2.514
2793	188.351	195.683	189.368	6.315	7.332	3.227	3.747
1516	190.644	196.991	194.74	2.251	6.347	1.143	3.222
9326	196.486	199.983	196.083	3.9	3.497	1.950	1.749
2731	195.644	200.842	198.171	2.671	5.198	1.330	2.588
9289	206.352	203.447	206.565	-3.118	-2.905	-1.533	-1.428
1521	202.564	205.354	200.105	5.249	2.79	2.556	1.359
9306	210.444	212.184	217.55	-5.366	1.74	-2.529	0.82
9275	227.493	225.95	229.793	-3.843	-1.543	-1.701	-0.683
9291	226.275	228.768	232.456	-3.688	2.493	-1.612	1.09
9321	232.573	232.419	230.799	1.62	-0.154	0.697	-0.066
9293	245.446	242.528	242.073	0.455	-2.918	0.188	-1.203
9294	270.168	270.547	269.257	1.29	0.379	0.477	0.140
Sum				18.639	16.367		
Mean				1.036	0.909		

Appendix 6. Traverse computation and coordinate result of reference points

St.	X-coordinate	Y-coordinate	distance	ΔX	Δy	Adjusted x coordinate	Adjusted y coordinate	Description
1	552940.885	1572600.372		0.000	0.000			CP32
2	553064.933	1572160.848	456.694	-0.020	0.019	553064.914	1572160.867	
3	553125.357	1571723.063	441.935	-0.039	0.037	553125.318	1571723.100	
4	553131.856	1571223.931	499.174	-0.060	0.058	553131.796	1571223.988	
5	553212.645	1570869.947	363.086	-0.076	0.072	553212.569	1570870.020	
6	553411.880	1570336.198	569.722	-0.101	0.096	553411.779	1570336.294	
7	553253.577	1570059.693	318.613	-0.114	0.109	553253.463	1570059.802	
8	553041.713	1569706.429	411.925	-0.132	0.126	553041.581	1569706.555	
9	552926.766	1569445.023	285.562	-0.144	0.138	552926.622	1569445.161	
10	553386.515	1569274.936	490.203	-0.166	0.158	553386.350	1569275.093	
11	553671.136	1569074.060	348.368	-0.181	0.172	553670.956	1569074.232	
12	553683.823	1568695.901	378.371	-0.197	0.188	553683.626	1568696.089	
13	553577.449	1568215.726	491.816	-0.218	0.208	553577.231	1568215.935	
14	553293.405	1567804.021	500.182	-0.240	0.229	553293.166	1567804.250	
15	552793.030	1567342.089	680.997	-0.269	0.257	552792.761	1567342.346	
16	552944.472	1566905.413	462.191	-0.289	0.276	552944.183	1566905.689	
17	553116.569	1566530.406	412.611	-0.307	0.293	553116.262	1566530.698	
18	553172.009	1566022.034	511.385	-0.329	0.314	553171.681	1566022.348	
19	553199.601	1565689.231	333.945	-0.343	0.328	553199.258	1565689.558	
20	552723.628	1565493.345	514.706	-0.365	0.349	552723.262	1565493.694	
21	552385.674	1565331.026	374.914	-0.382	0.364	552385.292	1565331.390	
22	551933.983	1565040.132	537.256	-0.405	0.386	551933.578	1565040.519	
23	551445.405	1564924.503	502.074	-0.426	0.407	551444.979	1564924.910	
24	551076.725	1564917.606	368.745	-0.442	0.422	551076.283	1564918.028	
25	550992.990	1564499.147	426.755	-0.461	0.440	550992.529	1564499.587	
26	550844.635	1564198.733	335.049	-0.475	0.454	550844.159	1564199.186	
27	550498.931	1563880.384	469.954	-0.495	0.473	550498.435	1563880.857	
28	550061.199	1563892.058	437.888	-0.514	0.491	550060.684	1563892.549	
29	549930.795	1564289.941	418.708	-0.532	0.508	549930.263	1564290.449	
30	549897.980	1564842.442	553.475	-0.556	0.531	549897.423	1564842.973	
31	549970.590	1565500.245	661.798	-0.585	0.558	549970.005	1565500.803	
32	550143.065	1566005.830	534.195	-0.608	0.580	550142.457	1566006.410	
33	550411.259	1566604.278	655.795	-0.636	0.607	550410.622	1566604.885	
34	550608.872	1566962.297	408.936	-0.654	0.624	550608.219	1566962.921	
35	550791.702	1567409.330	482.975	-0.675	0.644	550791.027	1567409.974	
36	551200.758	1567702.575	503.309	-0.696	0.665	551200.062	1567703.239	
37	551480.383	1568029.550	430.236	-0.715	0.682	551479.668	1568030.232	
38	551744.088	1568559.975	592.361	-0.740	0.707	551743.348	1568560.682	

39	552099.992	1569107.546	653.070	-0.769	0.734	552099.223	1569108.279	
40	552424.267	1569591.267	582.358	-0.794	0.758	552423.473	1569592.025	
41	552382.288	1569999.111	409.999	-0.811	0.774	552381.477	1569999.885	
42	552355.640	1570337.723	339.659	-0.826	0.788	552354.814	1570338.512	
43	552346.690	1570951.777	614.119	-0.853	0.814	552345.837	1570952.591	
44	552415.590	1571460.967	513.830	-0.875	0.835	552414.715	1571461.802	
45	552462.629	1571899.849	441.396	-0.894	0.853	552461.736	1571900.702	
46	552471.789	1572553.695	653.909	-0.922	0.880	552470.867	1572554.575	CP31 reading
47	552470.867	1572554.574						CP31
Total			21374.25	0.922	-0.880			
Linear miss closure error=1.275								
Relative precision of the traverse is 1:16,774.547=1:17000								

Appendix 7. Angular and distance measurement for total station traversing

Type	Typical accuracy	Purpose	Angular measurement	Distance measurement
Geodetic or precise	1 in 50,000 or better	<ul style="list-style-type: none"> ● Provision of very accurate reference points for engineering surveys ● Primary control surveys 	Use 0.1" industrial theodolite	Accuracy better than 1 mm required – use specialised electronic distance measuring equipment or industrial total station
General	1 in 5000 to 1 in 50,000	<ul style="list-style-type: none"> ● General engineering work including site surveys and setting out of structures and roadworks ● Adding secondary control to primary control networks 	Electronic theodolite or total station with accuracy between 1" and 10" required	Use total station or steel tapes to match accuracy requirement
Low accuracy	1 in 500 to 1 in 5000	<ul style="list-style-type: none"> ● Control for drainage schemes and earthworks ● Small-scale mapping 	Electronic or optical theodolite of 20" or lower accuracy required	Total station, steel or synthetic tapes can be used

Appendix 8. Total station working in the process of data collection.

