An app for land administration: criteria, functional requirements and a prototype in Ethiopia

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March, 2016

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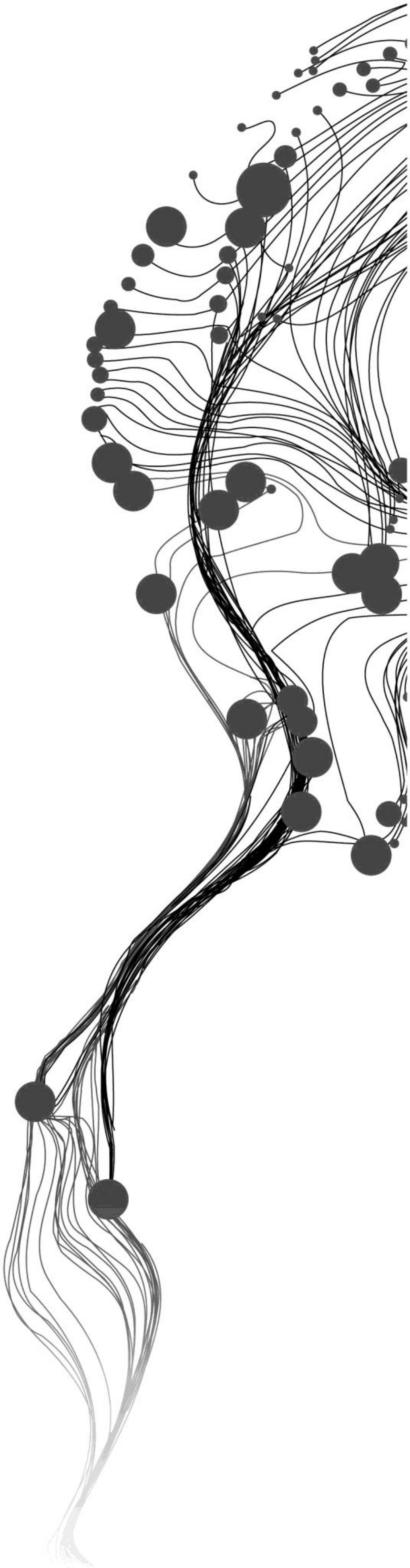

An app for land administration: Criteria, functional requirements and a prototype in Ethiopia

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ABSTRACT

Much of the world's land rights are not registered in government-recognized systems. In the developing countries, there is an urgent need for faster and cheaper registration processes. The land administration community is trying to find a solution on how this registration can speed up and include all land tenures. In order to avoid the costly procedures, land professionals considered a pro-poor and fit-for-purpose land administration form of land registrations.

Recent technological advancements in hand-held devices (including cell phones) are offering new opportunities for determining the geographic location through LBS (Location Based Services). Different apps and tools have been developed based on the requirements necessary for a pro-poor and fit-for-purpose land system. Those apps are aiding the land systems for a cost-effective and rapid registration. Despite the fact that they are developed for data collection, few of them are currently tested in the field and analyzed user satisfaction for cadastral data collection in rural areas.

This research is focused on the selection of an app, from the wide list of apps on the market, which has been assessed against pro-poor and fit-for-purpose and tested on the field. The mobile app selected should fulfil the user requirements. Identification of the users is made to understand their requirements and make the evaluation of the mobile app and methodologies based on mobile apps. The comprehensive research gives the necessary steps from selection, adaption and evaluation of mobile apps for cadastral data collection. In the end, the analysis of cost and time of such methodologies is done followed by the future improvements needed to the mobile apps.

Key words: *Apps, Mobile, Cadastral data collection, Pro-poor, Fit-for-purpose, User requirements, User Satisfaction, Prototype, Evaluation, Ethiopia.*

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Sincerely ,

Julinda

DEDICATION

This thesis is dedicated to the reason of every achievement, every single try and second of my life.
My daddy!
You are the reason of every breath and I hope to make you always proud. I adore and I love you!

Your Kukurruku

Kjo temë i dedikohet arsyes së çdo arritje, të çdo përpjekje dhe çdo sekonde të jetës sime.
Babushit tim!
Je arsyeja e çdo frymëmarrjeje dhe shpresoj të të bëj gjithnjë krenar. Të adhuroj e të dua shumë!

Kukurruku yt

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GLOSSARY

App	For application: a computer program or piece of software designed for data collection that can be downloaded onto a mobile phone or other mobile device [1]
Cadastre	"A parcel-based land information system that includes a geometric description of land parcels, usually represented on a cadastral map. In some jurisdictions it is considered separate from, but linked to, the register of land rights and holders of those rights (land register), while in other jurisdictions the cadastre and land register are fully integrated". (FAO, 2002)
Cadastral Data	Are defined as the geographic extent of the past, current, and future rights and interests in real property including the spatial information necessary to describe that geographic extent (Federal Committee Geographic Data, 2008)
Cadastral collection process	The activity including actions and steps for retrieving information for cadastre purposes like tenure information and boundaries information [1]
Fit-for-Purpose	Specific principles designed to support management of land administration systems and their design
Land administration	"The set of systems and processes for making land tenure rules operational. It includes the administration of land rights, land use regulations, and land valuation and taxation. Land administration may be carried out by agencies of the formal state, or informally through customary leaders". (FAO, 2002)
Land registration	"The recording of rights to land in some form of public register. It includes information on the rights, their location, and their holders. Registration can be parcel-oriented (sometimes referred to as title registration) or based on the holders or transfer documents (sometime referred to as deed registration). In title registration, ownership is transferred upon registration rather than on execution of the contract; the state may also provide a guarantee on the validity of the title". (FAO, 2002)
Pro-Poor tools	Tools in land administration designed to support poor people and communities
Prototype	Here is referring to first example of something, in our case the app, from which all later forms are developed [2]
Test	An act of using something to find out if it is working correctly or how effective it is[1]
User	Someone who uses a product, machine, or service here users are referring to land experts, land surveyors, land officers who will use the app excluding farmers, citizens, and persons who are not implemented on data collection

[1] Adapted from Sally Wehmeier, Colin McIntosh (2005)
[2] Adapted from Sally Wehmeier, Colin McIntosh (2005)

User perception	A belief or opinion of the user how the app seem [2]
User Satisfaction	A measure of how happy users feel when they use a particular service, in this case the app
New cadastral collection process	Different actions and steps, from the actual ones, on collection of cadastral data [2]

1. INTRODUCTION

1.1. Background

One of the central aims of land administration systems is to support tenure security. Land registration is a key part of the land administration process and is defined by Nichols (1993) as the official process of creating and managing land tenure information. Zevenbergen (2002) highlights that main goal of land registration systems is to provide security of tenure to the actual and/or future owners of land. The process of registration includes collection of data, and other important phases that conventionally require relatively large amounts of time and money.

Much of the world's land rights are not registered in government-recognized systems. The registration process is slow in many of the countries of the world: it is estimated that just 30% of the world's land rights are recognized and registered in a formal registration system (GLTN, 2012). Developing countries are the most problematic: the registration process has been going on for decades (Magis & Zevenbergen, 2014). There are several well-documented reasons for this: complex land tenures, impediments during the processes, and/or the fact that the registration processes are cost and time consuming. The methods used for collecting the data for cadastral purposes are often conventional surveying, aerial photogrammetric methods, terrestrial laser scanning and land surveying techniques (Aringer & Roschlaub, 2014). These methods provide the required accuracy, but in some cases their application is expensive for developing countries.

The land administration community is trying to find solutions that can speed up registration of all land tenures. In order to avoid the costly procedures, land professionals considering pro-poor land administration options that build upon the philosophy of continuum of rights (Zevenbergen, Augustinus, Antonio, & Bennett, 2013). Pro-poor land recordation systems should support the rights of poor people, be affordable, and be practical to be enclosed within public institutions (Zevenbergen, Augustinus, & Antonio, 2012). Different tools, including apps, have been developed based on the requirements necessary for these pro-poor land administration systems. The apps are intended to aid cost-effective and rapid registration. Tenure security cannot be catered for by only providing individual land titling: the implementation of the continuum of land rights is essential to allow the people get onto the property ladder (Zevenbergen et al., 2013).

In this framework, recent technological advancements in hand-held devices (including cell phones) are offering new opportunities in determining the geographic location through LBS (Location Based Services) (Gartner, Meng, & Peterson, 2007). Apps provide a new alternative. Most spatially enabled apps are based on a GIS (Geographic Information System) and provide the power to create maps, integrate information, visualize scenarios, and present powerful ideas (US EPA, Region 3, 2015). Indeed, several GIS based mobile apps can be found on the market that enable collecting data, storing, mapping, navigation and inheritance of different roles. However, there is diversity amongst the existing apps: design, implementation, testing areas, availability, backend support, costs, accuracy, offline functionality, can be organized quite differently amongst apps. In this vein, McLaren (2011) analyzed how newly developed applications running on platforms such as smart phones could support geographic and crowd information services. McLaren (2014) based his ideas on developing new approaches such as the MapMyRights concept: a global platform that aimed to give citizens the opportunity to record evidence of their land rights. Realization of the concept is beginning to occur: some of the apps are already being tailored to collect data for land administration purposes such as adjudication, recordation and demarcation. However, much remains unresolved in terms of technical requirements, uptake potential, scalability, and so on.

1.2. Justification

The demand for more fit-for-purpose data collection processes has led to the development of apps for the facilitation of spatial data creation. Although these apps may be developed for data collection, most of them are not specifically designed and tested for land administration purposes. Before implementing new technologies (mobile app) on cadastral data collection and registration processes, a deeper needs and readiness analysis should be undertaken. In case of cadastral data collection, users of the system are usually land officers. Gathering their perceptions allows us to understand expectations regarding implementation, design, results and analysis. User satisfaction is defined from (Ives, Olson, & Baroudi, 1983) as an evaluation mechanism for what users believe about how products or services meet their requirements.

Ethiopia is one of the countries where pro-poor and fit-for-purpose tools have already been embraced. The process of registration in Ethiopia has 2 phases: first registration was done based on textual descriptions of the parcels, whilst second registration (started in some regions of the country) includes with the certificate of ownership a map with the boundaries of specific parcel. In Ethiopia people to land interactions are characterized by tenure insecurity, arbitrary evictions, and inequality of landownership (Deininger, Ali, Holden, & Zevenbergen, 2008) – both in rural and urban areas. On the rural side, agriculture is the first source of food and incomes for 90% of households so the registration process need to be improved. The focus of this research is on rural areas: 1) it is where the research is expected to have the biggest impact, and 2) it is where the accuracies available from the tool are expected to be most acceptable. Land administration modernization has already been occurring in rural areas (Alemie, Bennett, & Zevenbergen, 2015) – although, cities also. However, It is argued that Ethiopia needs to speed up the second registration processes using the emerging data collection methods.

1.3. Research Problem

Different apps on the market give the opportunity to collect data. Depending on their characteristics, some of the apps can be used for cadastral data collection in order to reduce time and costs, especially in developing countries like Ethiopia. Despite the fact that they are developed for data collection, few of them are currently independently tested in the field and analyzed for user satisfaction with regards to cadastral data collection in rural areas.

1.4. Research Objectives and questions

Main Objectives

To apply and evaluate an app that could be adapted for use to support pro-poor and fit-for-purpose land registration.

Sub Objectives

1. To identify the apps available for cadastral data collection and assess them against criteria for pro-poor and fit for purpose land administration
2. To discover user requirements and system requirements for cadastral data collection in Ethiopia
3. To adapt, develop, apply and assess a new cadastral collection process for the case of Bahir Dar Zuria, Ethiopia
4. To analyze user satisfaction regarding the mobile app and the process of data collection

Research questions

Sub objective 1

a) What apps are available for data collection in land administration?
b) What are the criteria for creating pro-poor and fit for purpose land administration systems?

Sub objective 2

a) Who are the specific actors of the app in the context of Ethiopian land administration?
b) What must an app be capable of from functional and technical perspectives in order to support Ethiopian registration?
c) What app is most suitable to be tested in Ethiopia?

Sub objective 3

a) How can the app be embedded into the cadastral data collection process?
b) How might be design and develop/prototype a new cadastral collection process.
c) What differs from the conventional cadastral data collection process?

Sub objective 4

a) What is the opinion of users of the implemented mobile app for cadastral data collection?
b) What improvements to the app can be made from the user perspective?
c) What are the potential improvements to the cadastral data collection process in terms of time and operating costs?

1.5. Conceptual Framework

The main concepts underlying the research, as will be discussed in Chapter 2, are: APP, Cadastral Data Collection, Users and Evaluation (Figure 1). As it is represented in the conceptual framework, there are four bobbles which represent the main focus of research. The first step start is on the Apps, with two directions, User and Cadastral data collection. In the middle of the design, there is the bobble of evaluation which is the final result of the research. Throughout the research process, the concepts interact. The app designed for cadastral data collection is selected based on pro-poor and fit-for-purpose land administration criteria. The app was tested with potential users for cadastral data collection. After the test, the users opinions are used to evaluate the mobile app and the new methodology

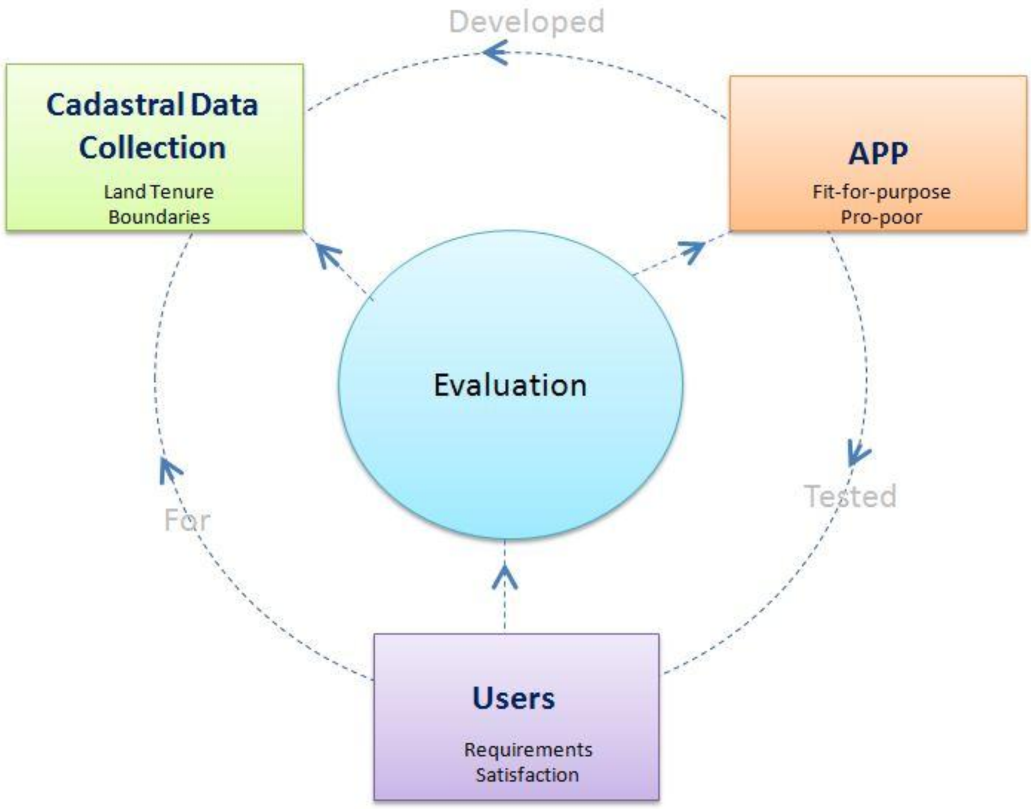

Figure 1. Conceptual Framework

1.6. Research Matrix

The research matrix (Table1) is developed do give an overarching view of the objectives, questions, and intended methods (as justified later in Chapter 3), data sources, and anticipated results.
Are visualized in a more compact way the 4 sub-objectives. The second column shows the research questions followed from the column of the research methods used during research. The method used is written in the third column and the last 2 columns are written respectively: sources needed for collecting and analyzing information to give answers to the research questions and finally the anticipated results which are the results of the research.

Table 1. Research Matrix

Sub Objectives	Research Questions	Methodology	Data Collection Source	Anticipated Results
1. To identify the apps available for cadastral data collection and assess them against criteria for pro-poor and fit for purpose land administration	a)What apps are available for data collection in land administration? b) What are the criteria for creating pro-poor and fit for purpose land administration systems?	Desk Study Synthesis Review	Documents/Reports Web Pages Literature Existing Literature review	A list of apps available for data collection A list of criteria's for pro-poor and fit-for-purpose and their description
2. To discover user requirements and system requirements for cadastral data collection in Ethiopia	a) Who are the specific actors of the app in the context of Ethiopian land administration? b) What must an app be capable of from functional and technical perspectives in order to support Ethiopian registration? c) What app is most suitable to be tested in Ethiopia?	Desk study Interviews	Existing literature Key-informant Interviews	List of users and their role in the process List of requirements for Ethiopia Selection of the app to be tested and its characteristics
3. To adapt, develop, apply and assess a new cadastral collection process for the case of Bahir Dar Zuria, Ethiopia	a) How can the app be embedded into the cadastral data collection process? b) How might be design and develop/prototype a new cadastral collection process. c) What differs from the conventional cadastral data collection process?	Workshop Design/Develop workflows Field measurements	UML Laptop ESRI License Mobile &Handle GNSS Second registration data	Workflow with all the steps to implement the app into cadastral data collection Steps to undertake for prototyping a new collection process Results of tests of the app directly on the field with the users
4. To analyze user satisfaction regarding the mobile app and the process of data collection	a) What is the opinion of users of the implemented mobile app for cadastral data collection? b) What improvements to the app can be made from the user perspective? c) What are the potential improvements to the cadastral data collection process in terms of time and operating costs?	Interviews Group Discussion Questionnaires	Semi-structure Interview with users Focus Group discussion Questionnaires	Evaluation of the results for the app and methodology Analyzing the elements users find necessary to be improved Analysis of time and cost regarding this app

1.7. Thesis structure

The provisional thesis structure consist of:
Chapter 1: Introduction - articulates the topic, including the research problem, research questions, main concepts and research matrix are covered.
Chapter 2: Literature Review - is a chapter where we refer to other works related to the main concepts of research.
Chapter 3: Research Methods - explains in detail, the methods are used for data collection, data gathering and data analysis.
Chapter 4: Criteria's and requirements for a mobile app - includes the main pro-poor and fit-for-purpose criteria's, moreover functional and technical requirements of land experts.
Chapter 5: App Selection - includes the list of app selected for the research. The main information about the app and the steps for selection of an app are provided.
Chapter 6: Adapting and Applying a mobile app in Ethiopia - includes steps for adapting the mobile app for data collection, the steps designed for testing the mobile and a comparison of the data collected with the app with data collected with the conventional method.
Chapter 7: Evaluation and Discussion – gives firstly the users and their role in second registration in Ethiopia, and then articulates the user opinion about the method and evaluates the professionals opinions based on the required elements. Moreover, a cost analysis is done regarding both methods. In the end, the discussion of the thesis
Chapter 8: Conclusions and Recommendation – covers for each sub objective and in the end lesson learned and future recommendation.

2. LITERATURE REVIEW

This chapter provides a theatrical background on the key concepts related to this study. Different concepts are covered, and brought together, including pro-poor, fit for purpose, cadastre, data collection methods, technology supporting land administration, mobile GIS, VGI, crowdsourcing, land reform and land registration in Ethiopia. Each concepts is needed to help development and assessment of a new app-based method of cadastral data collection. The concepts are first defined and farther on are expanded upon – and linked to the research - using academic and grey literature.

2.1.1. Understanding the Cadastre

The role of the cadastre is argued as a tool for explaining the link between person-right-parcel by answering the questions like who? where? how much? And how? (Henssen, 2010). Nichols (1993) defined cadastre as the "*identification and description of land units which individuals or groups have rights of occupation, use or ownership*". A cadastral system is conceptualized as a model (sometimes 3D) of legal, institutional and technical, where is register the legal attribute and technical attribute, associated with the spatial information of the specific parcel (Yavuz, 2005).

The first known cadastres were hand drawn plans of different properties in ancient Mesopotamia and Egypt (2300 B.C), but the first maps discovered endure from the Ptolemaic period (305-30 B.C) (Kain & Baigent, 1992). In that period the main reason for drawing plans was for taxation. The origin of modern cadastre is often ascribed to Napoleon. Modern cadastres are generally derive from three main purposes: the legal cadastre that supports land markets; the fiscal cadastre that support the land taxation; and the multipurpose that supports all LAS processes. Division on Engineering and Physical Sciences (1983) prescribe the multipurpose cadastre as the base for registering land data and linking those data with other files located on the same jurisdictions and governmental units.

Somehow a fuzzy distinction exists between land registration and cadastre. Convention suggests cadastral systems have two components: a legal or administrative part and a technical part: the first one is responsible for creating a good recording system of the rights and for adjudication, and the second one is responsible for creating the mapping and cadastral surveying (I. P. Williamson, 1983). However, until recently, and perhaps even in current times, cadastre and land registration were often difficult to distinguish because of a missing universal definition (Zevenbergen, 2002). Many of the countries in the word have separate organizations for organizing cadastres and land registration activities, although their difference in functionality, they have a strong connection with each other (Steudler, Törhönen, & Pieper, 2010).

Developed countries, referring to the EU (European Union) countries, have experienced long process in establishing their digital cadastral and registration systems (Yavuz, 2005). Meanwhile, according to Tuladhar (2003), cadastre and land registration in the developing countries need a lot of changes. This has been a common mantra for several decades. Cadastres should be based on some principles and rules which should provide systematic and trusted information about parcels (Steudler, Rajabifard, & Williamson, 2004). Different visions for cadastral development were developed for implementation, for example, those of Kaufmann (1999) espoused in the document known as Cadastre 2014. However, despite these grand visions and good intentions, in the current period land administration still faces problems in developing countries: problematic methods, often still based on paper, exist.

2.2. The emergence of pro-poor & fit-for-purpose

Many conventional land systems do not provide security or legal support for the complete continuum of rights, especially those tenures of poorer communities. It is now argued that security of tenure cannot be catered for by only providing individual land titling (Zevenbergen et al., 2013). To make viable the access to tenure security of the poor it is necessary the development of innovative new approaches (Enemark, McLaren, & Molen, 2009). Indeed, it is argued that developing countries need to implement approaches that support fit-for-purpose, faster and cheaper cadastre (Hackman-Antwi, Bennett, de Vries, Lemmen, & Meijer, 2013a).

Pro-poor land records were identified by the Global Land Tool Network as one out of 18 new land tools for improving global land tools (Zevenbergen et al., 2012). Pro-poor was designed to reduce poverty and to take into consideration the rights of the poor (GLTN, 2012, p. 8). Within the development of pro-poor started the development of different tools like Social Tenure Domain Model (STDM), a tool and model for recording the different types of tenure of the poor (Lemmen, 2010). The design of a pro-poor land system can be useful for those countries where land recordation is facing problems on management. According to Zevenbergen, Augustinus and Antonio (2012) pro-poor systems should have designs that are: affordable, simple, quick, able to improve record accuracy, and avoid of costly fees.

Meanwhile, the idea of 'fit for purpose', stemming from Enemark, Clifford, Lemmen, & McLaren (2014) "*indicates that land administration should be designed to meet the needs of the people and their relationship to land, to support security of tenure for all and to sustainably manage land use and natural recourse*". Enemark et al. (2014) elucidate that fit-for-propose is based on the idea that land systems should be designed with a specific purpose like poverty reduction, access to the land, social equity, food security, good governance, environmental protection - and not just following the technical standards. That is, "*accuracy relates to the purpose rather than technical standards*" (Enemark et al., 2014). R. M. Bennett & Alemie (2015) explain that the ideologies of fit-for-purpose are already affecting Ethiopian cadastral design by implementing elements and principles of fit-for-purpose, one of those cases is Bahir Dar.

2.3. The evolution in spatial data collection methods

Historically, spatial data collection in cadastral systems were ground-based: these are the basic approach in most of the cadastral systems worldwide for sporadic measurement and photogrammetric techniques which are more used for systematic adjudication of large-scale areas (I. P. Williamson, 1983). Aerial photography methods are more recently applied. I. P. Williamson (1983) identified in Thailand that photogrammetric could be used where physical boundaries exist. However, its applicability might not be as suitable in urban areas, areas with high vegetation, lack of financial resources, and where a sporadic approach is demanded. At any rate, both techniques are well used, but both have advantages and disadvantages – and can be potentially applied together.

During the last decades, techniques for collection of cadastral data have progressed from conventional ground-based surveying to more sophisticated methods utilizing GPS, LiDAR and satellite imagery (R. Bennett, 2007). GPS or GNSS has been the most disruptive (Lemmens, 2011). GPS is a surveying tool that can achieve high precision surveys that allows to measure without need of other machines, used mostly for fix boundaries, marks and occupations that later you can link those data with other points (Surveyor-General & Victoria, 2004). Despite the accuracy, the cost of the high-precision equipment is quite considerable.

In developing contexts, implementation of low cost technologies for the cadastral mapping is suggested (Kurwakumire & Chaminama, 2012). Geospatial Media and Communications (2015) analyzed the differences between the cadastral systems in developing countries in comparison with western European countries: one of the factors that influence the success of the systems is appropriate technology selection.

In this regard, rapid development of other technologies including sensors networks, mobile applications and cloud computing are changing the way, if not providing new opportunities, how geographic information is collected, stored, updated, analyzed and visualized more generally (Sui, Elwood, & Goodchild, 2012). Referring to Heipke (2010), the technology of geo-referencing with GPS or mobile positioning fused with broadband communication can be successful as it enables the fast distribution of information collected and the easy way of using the technology.

Data collection using mobile applications with LBS is increasing widely. Park (2015) mentioned some of the advantages of using mobile systems for data collection including rapid pace, real-time access that will improve the quality of data, reduction of risk of errors and losses of data. Earlier studies such as (McLaren, 2014);(Pullar, Mcdowell, Solovov, Manoku, & Rizzo, 2012);(USAID, 2015a) showed that mobile apps with LBS are effective for cadastral data collection. Recent tests were completed in Colombia. Molendijk, Morales, & Lemmen (2015) determined the approach of a mobile app for cadastral data collections as fit-for-purpose, could-based database structured based on Land Administration Domain, and this would give the opportunity to collect and verify data.

Another type of GIS technology affecting the different fields is OpenSource Software. The capacity of open GIS software is high and the can be used, adapt, distribute, modify and copy for any purpose spatial information, helping in providing basic and advance analysis and visualization techniques (Neteler, Bowman, Landa, & Metz, 2012).

2.4. The impact of the new methods on land administration

The impact of new technology on land administration to support sustainable development, have been discussed by Ian Williamson, Enemark, Wallace, & Rajabifard, (2010): they conclude that technology will stimulate new concepts, new cadastral data models and new approaches in GIS. R. Bennett (2007) shows how the above emerging technology might be applied to land administration and considered the potential of spatial technologies to change functions of society and government, making the display of the information as a picture to be understood better from people. Indeed, "*Land Administration systems(LAS) are now changed by new technology*" (Wallace, Williamson, Rajabifard, & Bennett, 2006). Implementation of technology is changing the nature and content of land administration including aspects related to complexity of spatial information, relativity of land information, content of land information, land and resource regulation, restrictions and responsibilities (Wallace et al., 2006).

One of the basic benefits of using new technology is reduction of time for collection processes. Time, costs, and data accuracy remain important characteristics for measuring the productivity of those collection methods and these can arguably be enhanced with the adaption of technologies (Park, 2015). However, user needs also remain central: the success of land administration will be the result of using the appropriate technical solution, where technology should support: user driver to include formal and informal, and development of the country (Ian P Williamson, 2001).

The development of technology brought a new vision for collecting geographic information. One of those visions which started to be the future and promising of a lot of GIS systems were VGI, crowdsourcing or neo-geography. The term VGI was termed for the first time from Goodchild (2007) after observing the phenomenon of volunteer citizens collecting, creating and sharing different geographic information. The term crowdsourcing refers to process of data collection from a large number of non professionals (Heipke, 2010).
Regarding neo-geography, the citizens who collect data and create their own map to share with different people(de Vries, Bennett, & Zevenbergen, 2015). The above mentioned processes can be even described as "participatory mapping" (Brown, de Bie, & Weber, 2015).

The implementation of VGI, Crowdsourcing or neo-geography has increased a lot. There have been different web platforms or scientific field approaching this methodology of data collection. This idea has been raised for implementing crowd source in land administration systems in different studies such as (McLaren, 2011); (McLaren & Stanley, 2011); (Kalantari & Rajabifard, 2012); (Keenja, De-Vries, & Bennett, 2012). One experiment carried out in Greece from Basiouka & Potsiou (2012) conclude VGI/crowdsourcing as good possibility for reducing cost and speed up cadastral processes. The benefits of implementing crowdsourcing are delivering effective services, accessibility of the information (McLaren, 2011), reduce cost of registration (R. Bennett & van der Molen, 2014), interaction of citizens with government (Sieber & Johnson, 2015), better management of cadastre rights, restrictions and responsibilities (ICSM, 2014), transparent land systems, improve governance (Kalantari & Rajabifard, 2012).

Before adapting crowd techniques need a better studies are needed for affectedness of VGI in land administration issues (Basiouka, Potsiou, & Bakogiannis, 2015). Cadastral institutions will need to adapt to methodologies, operations and policies (R. Bennett & van der Molen, 2014). Moreover, the preferences of land professionals are more about standard systems as STDM rather than VGI or open source (Laarakker & de Vries, 2011).

2.5. Land Reform in Ethiopia

Before the reform of 1974, land reform in Ethiopia differed in the North from the South of the country due to the influence of the communist regime. The north part of the country had a communal *rist* system contrary to the south where landlordism was absent (Holden, Deininger, Ghebru, & Management, 2011). With the implementation of new reforms, the situation in the country changed: land became a property of the state while the citizens retained the right of use. The distribution of the land was decided based on the needs of a household. The restrictions made to the rights of use were substantial, starting with the size (maximum 10 ha) of the land and moreover renting or hiring was prohibited.

In 1991, the situation changed following governmental changes. The restrictions on land rights were lifted so that citizens could rent or hire land although, with some other restrictions. The government made changes in the responsibilities, rules, laws, land registration and certification procedures by developing the regional land proclamations. Proclamations are an official announcement made to the public (Sally

Wehmeier, Colin McIntosh, 2005). The proclamations in Ethiopia include Federal Land Proclamations (FRLAUP, 1997; FRLAUP, 2005) and Tigray Land Proclamations. Proclamations include all the laws, rights and restrictions regarding land tenure, and the right of use and associated subdivision rules. In Amhara, a new draft proclamation was prepared in 2005. The land administration was done by the Land Use and Administration Proclamation.

Even though there were different changes over time, still the ownership of land is possessed by the government of Ethiopia and the farmers only have the right to use. The plots cannot be mortgaged, sold or exchange, but can be inherited, rented and transferred. In cases of divorce, the wife gets half of the land (Deininger, Zevenbergen, & Ali, 2006) & (FRLAUP, 2005). At any rate, the situations allow the government the right to remove farmers or holders of the land and gave millions of hectares to foreign investors with the belief that this will develop agrarian structure, increase production and will reduce the poverty (Rahmato, 2011). Despite the fact that government allows implementation of different projects for supporting sustainable developments and for increasing investment, based on the five years GTP (Growth and Transformation Plan), the proclamation of Ethiopia is argued to be not fast-tracking implementation of the projects (Belay, 2014).

2.6. Land Registration in Ethiopia

The first certification in Ethiopia was done for the Tigray people: the holders of land were provided with paper containing the name of the holder, family member (size), parcel size, boundary information, neighbors of the parcels and soil fertility status. Despite the fact that the certification was developed to reduce the conflicts and to increase the tenure security, it was not included in the central Registry. The certification consisted of 4 forms; form 1 is the collection of data, form 2 register in the community book, form 3 is the certification distribution to landholders and form 4 are land transactions (Holden et al., 2011). During this process, 88% of the rural householders were accredited with a certification. In the Amhara, this study's area of interest, a rate of 79% for registration was recorded, however, many concerns were raised in regard to human and financial problems, missing maps and weak material for demarcation (Deininger, Zevenbergen, & Ali, 2006). In the same region, some pilot cadastral mapping studies using total stations and GPS have taken place, but the cost was very high.

The land administration functions, like tenure recognition, need to collect data in a fast and cheap way, to complete the cadastre in post-conflict areas (Hackman-Antwi, Bennett, de Vries, Lemmen, & Meijer, 2013b). The government of Ethiopia has faced for years different problems related to the land like: land grabbing, land conflicts, land acquisition and forced eviction. The large-scale acquisition of land by foreigners and the high number of conflicts between the landholders and government, bound the government to start implementation of land certification and registration. Consequently, in 2001 policy and strategies were developed that has a focused on large investors and they made a plan, which started in 2011, and was planned to finish in 2015, were was included the start of second registration of the land (Rahmato, 2011).

Ethiopia is one of few countries in the world which managed to register the majority of the rural land using low cost system and methods, with the recognition of customary rights, woman rights and aid on a better system of creation, recordation and maintenance of documents needed for the titling process (Deininger et al., 2008). Meanwhile, Ethiopia has begun the second registration and certification in specific regions, including the Amhara region, where the aim of the second phase is to increase tenure security by land management, maintenance and record updating (Bezu & Holden, 2014).

3. METHODS AND RESEARCH DESIGN

Having provided the theoretical setting for the work, this chapter articulates the necessary steps needed to answer the research questions. It gives a complete notion on how the research study stems from the selection of study, the collection of data, up to analysis of the data in a manner to achieve a relevant result and communicate findings. The research design explains rationale how will the process of research make possible all the steps and with specific justifications why specific methods were selected.

3.1. Study Area

The reason why the selected area for conducting this research was Ethiopia was because is a country approaching pro-poor and fit-for-purpose criteria's with an urgent need for fast registration. The selection of the region was Amhara because was the region where the second registration was taking place. Amhara, with capital Bahir Dar, is one of 9 ethnic divisions in Ethiopia. The region is divided into 10 other important administrative zones and second-level administrative areas are called woreda (total 108 woredas) which are composed of a number of wards (kebele). It is one of the most important regions where a registration process covering 99% of the land was undertaken. The last and highest level of registration is a second level book of holding (Belay, 2014). The government body responsible for the registration in woreda are Land Administrative Committees. There were done some pilots for registration with the implementation of GPS and GNSS, but this resulted in a high-cost process amongst other problems (Deininger et al., 2006). Despite the fact that a registration was done still a lot of woredas are in the process of second registration or update of individual, communal and service area boundaries. In this regard, it was considered a highly suitable location for app testing. The study area was focused in the woreda of Bahir Dar Zuria, West Gojam where the process of second land registration in Feres Woga

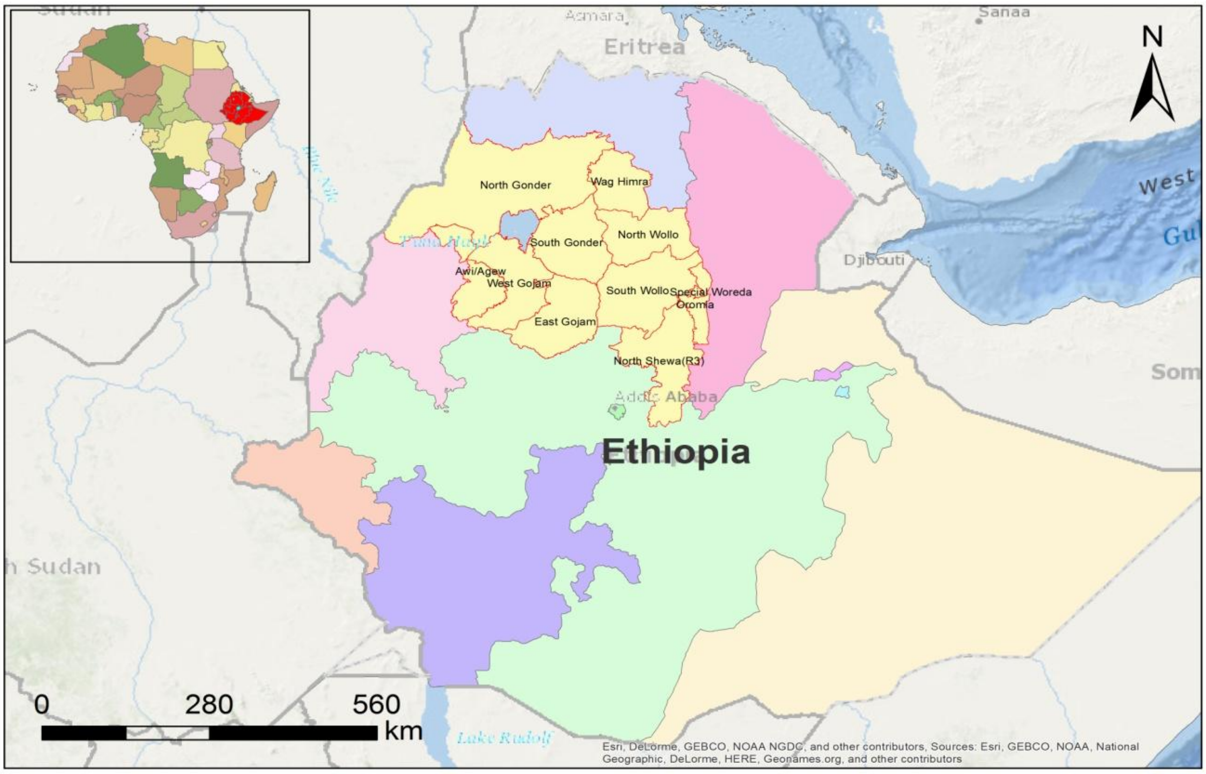

Figure 2. Study Area Map (Own source)

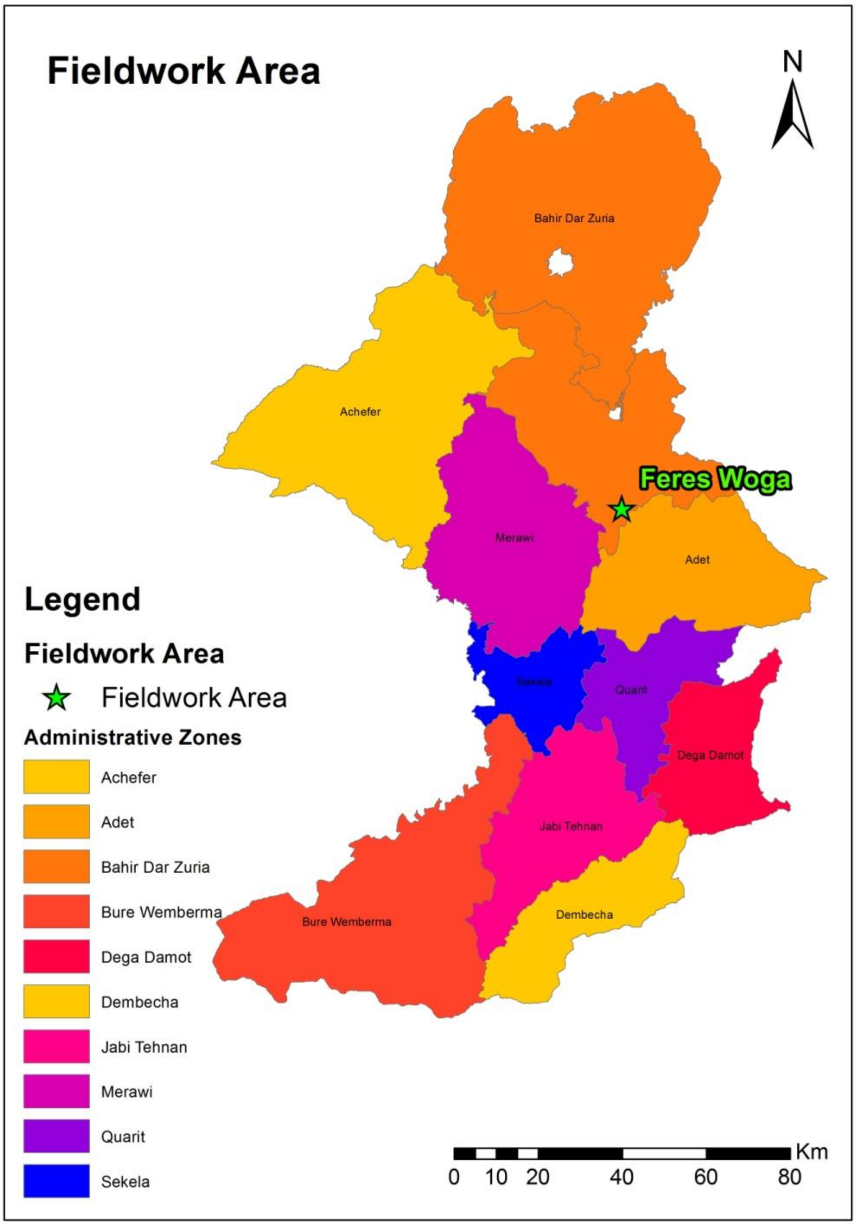

Figure 3.Fieldwork Area-Feres Woga (Own source)

3.2. Research design

This research evaluates and measures the impact of a potential new process on the satisfaction of the clients with the services. A part of the data were collected from desk study and synthesis literature and the other part of the data were collected during fieldwork, with a combination of semi-structured interviews, focus group discussions, and questionnaires - to understand user perceptions for the selected app and the applied methodology during fieldwork. For a better understanding of the steps followed and methods used to answer the objectives of this research refer to Figure 4.

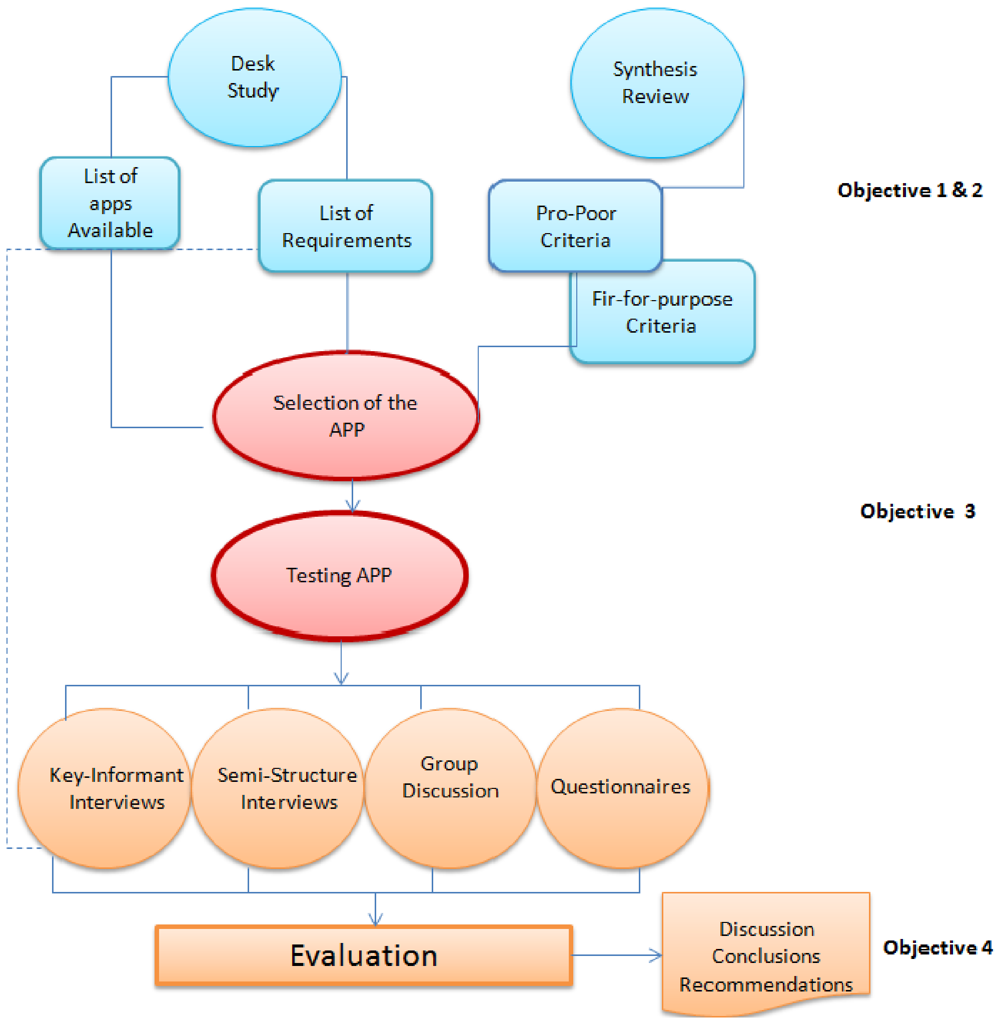

Figure 4. Research deign steps and methods

3.3. Methodology

In this section of the thesis are described the methods used in the 3 phases of the research. Before fieldwork, in fieldwork, and after fieldwork. The methods used for data collection and data analysis with the precise description why was selected this method and what was the result expected from applying each of the methods in this research.

3.3.1. Pre-fieldwork phase

In this phase of work, information is collected from different literature sources including books, papers, governmental reports and previous studies conducted in the same field. From the literature review, the study area, the research problem, questions, and methodology were defined. A broader desk study was done to retrieve information for different apps that were available. A synthesis matrix was used to identify the pro-poor and fit-for-purpose criteria's, which gives the opportunity to sort and categorize better the information collected. During this phase, key-informant interviews were conducted with 4 professionals with experience in land administration and previous experiences with mobile apps. The other 2 key-informants interviews, planned with land professionals in Ethiopia, were conducted in fieldwork phase because was not possible to conduct them before . This did not affect the selection of the mobile app.

3.3.1.1. Key-Informant Interviews

The key-informant interviews collected information from people that were intimately involved in the registration process in Ethiopia, or cadastral data collection more generally. This includes land professionals, project consultants, and so on. There were conducted 6 key-informant interviews: 1 from the Kadaster International, the international arm of Dutch Kadater, in Apeldoorn who has experience in testing the same app in Colombia; 2 academics in ITC with experience in Colombia and experience in Ethiopia regarding land registrations in poor countries; 2 residents in Ethiopia which had knowledge about the land administration in Ethiopia; and 1 professional that had experience with another app (MAST) in a developing country, Tanzania. A focus was given to the questions related to requirements technical and functional aspects an app should have for supporting cadastral collection process and registration context.

3.3.2. Fieldwork phase

The fieldwork duration was 3 weeks and included a combination of methods.During the fieldwork, a collaboration with Bureau of Environmental Protection, Land Administration, and Use (BoEPLAU) made possible an interaction with the potential users of the system, which were land professionals working on Land Administration Committees (LAC), and dealing with data collection in woreda or kebele level. A workshop was done with the users: workflows were developed with actual and new steps to undertake regarding the implementation of the new cadastral collection process. Furthermore, the app selected for study was tested with the users in an area where the second registration was taking place, in Feres Woga kebele. After the test, through semi-structured interviews, information about the perceptions of users was gathered. A focus group discussion was carried out with the users where the results of the field testing were discussed. Besides, a comparison of the data and method was made to assess the time and cost of implementing the app in practice. This phase focused on the collection of information in order to identify the elements of the systems, user role, user expectations and carried out the test for the mobile app. All those elements are required to answer the research questions.

3.3.2.1. Sampling of the case study area

In this research, the selected groups were land officials and land professionals implemented in the cadastral collection process in Ethiopia, specifically in Bahir Dar. In a land office, in woreda, there are working around 7-15 people. The people selected for interviews and questionnaires were professionals like surveyors or land officers that were involved in collection and registration process. The selection was made based on a judgmental sampling.

Selection of the measured parcels was made from the field team which has a graph of daily measurements they need to complete in that area. Meanwhile, the kebele where the measurement took place was selected because was in the process of second registration during field work visit. In total, 47 parcels were measured with GNSS in Feres Woga kebele. The parcels measured includes a variety of data, terrain, and land tenure. Parcels with high vegetations, where the first registration was missing, common land, different parcel geometry (e.g. curved boundaries), were selected.

3.3.2.2. Semi-structured Interviews

Semi-structured interviews are preferable to avoid limitations in answers, in this way is possible to achieve all the information needed (Bryman, 2012). The interaction between the researcher and responders gave the opportunity to explain the questions or in cases even to retrieve extra information. Moreover, the semi-structured interviews were conducted in order to retrieve the opinion of the users without getting affected by other people's opinions inadvertently. The number of semi-structured interviews undertaken was 10. There were interviewed 3 professionals from BoEPLAU, 1 expert from Woreda, 2 experts working on the REILA project, 1 expert working for the LIFT project, 1 person working on BoEPLAU, and 2 experts from Ministry of Agriculture. The semi-structured interviews were based on themes based on the research questions (Appendix 1). The themes were: second registration; users and their role in land registration; difficulties that are faced on the second registration; cost and time; and personal opinion about the new approach. The information from the semi-structured interviews was quite broad in terms of information retrieved. This information was used mostly to understand users opinion for implementing a mobile app. In some cases, explanations and extra question were done based on the topic or for retrieving extra information. Different from what was planned, the semi-structured interviews helped in the same way to identify the improvements can be made to the app from user perspective.

3.3.2.3. Focus group discussion

After conducting semi-structure interviews, group discussions were undertaken. Though discussions with the users were more productive in providing specific and diverse information, the group discussion enabled inclusion of the opinions of people who were not interviewed personally. Information that was collected from the 2 focus group discussion was: firstly, (workshop) participant's actual involvements and their discontent with existing processes. This was done in order to support designing new steps, and avoiding actual gaps. The second group discussion analyzed the impact of the user of the app: differences with the actual data available and actual methods were discussed. The focus group was open to all interested parties that wanted to participate. A presentation where it was explained briefly the research and a deep explanation about the app tested on the field was given. After the comparison of the data and an understanding of the method, the participants were given time to ask questions and give the opinion about potential implementation.

3.3.2.4. Questionnaires

A questionnaire approach was selected to assist creating and understandings of what the perception of the users towards the app was. Only professionals were included because firstly most of the landholders (farmers) could not read and write, and secondly, in Ethiopia, a full participatory mapping is not yet included as an option for land data collection in the field. In total questionnaires carried out were 10. Where 4 from field data collectors and other 6 from people who participate in group discussion. For the content of the questionnaires refer to Appendix 1. The field team questions were based on the experience they had using the app for measuring the parcels on the ground. The group discussion participants questions were based on their opinion regarding the mobile app and the actual methodology.

Questionnaires gave a broader view of advantages and disadvantages of the methodology and the required functions of the app from the user perspective. The perception of the users for the improvements in term of cost and time were part of the questionnaires.

3.3.3. Post-fieldwork phase

The post-field phase included the processing of the data. The interviews were analyzed manually using content analysis, whilst descriptive statistics were applied to the questionnaire data. The result of this phase are the user evaluation regarding the mobile app and the methodology used in Amhara. The last step included developing discussions, conclusions, and recommendations.

3.3.3.1. Data processing methods

Content Analysis: was the selected method for analysis of semi-structured interviews data that were collected. The method was selected to give the possibility of analyzing the data in an objective fashion. Content analysis is based even on the perception of the listener about the conducted interviews. Most of the interviews have been transcribed word by word. The other part of the interviews were listened to and was retrieved the main information summarizing the interview. From content analysis were defined the elements land expert need and find necessary for completing cadastral data collection. From the interview the mast specific phrases were quoted in order to show specific opinion of the users regarding the app and regarding the methodology.

Descriptive Analysis: This method was selected to analyze the result of questionnaires conducted for the evaluation of the app. This method was selected to summarize data dependent on their content. The contents of the questionnaires were mostly about the functionality of the app and the costs. Users that use the app in the field provided their perception about the app and the actual methodology. The questionnaires made on the group discussion include suggestions about the development of the app on the future and question related to the cost and time. Here the result of descriptive analysis is shown on chapter.

To summarize with content analysis were analyzed key-informant interviews, the result were list of requirements visualized on chapter 4. Moreover, were analyzed semi-structured interviews, he result were the identification of advantages and disadvantages of the new methodology represented in chapter 6. The result of the semi-structured interviews helped in the user evaluation.
With descriptive analysis were analyzed the questionnaires were identified the opinion of the users about methodology. A combination of elements identified from content analysis with descriptive analyses was done to achieve the results and to include all possible information.

4. CRITERIAS AND REQUIREMENTS FOR A MOBILE APP

In this chapter are identified the requirements a mobile app need to have to be used for cadastral purposes. Firstly a revision of pro-poor and fit-for-purpose based on earlier studies was done. Moreover, were identified the requirements land experts with experience in land administration and land experts currently working in Ethiopia found important for a cadastral data collection. Those elements are divided into functional and technical requirements.

4.1. Pro-poor and fit-for-purpose criteria's for land administration systems/tools

The criteria's of pro-poor and fit-for-purpose in this research are bases for selection and evaluation of implementing a mobile app into cadastral systems. The listed criteria's (Table 2) were identified from literature with a focus on improvement of land administration processes or systems. The elements of designening pro-poor were summarized and selected from the report published from UN-HABITAT for designing pro-poor cadastral recordation systems (Zevenbergen et al., 2012). The elements of fit-for-purpose were identified from a publication of FIG and World Bank about fit-for-purpose land administration (Enemark et al., 2014). A synthesis review was done to understand the meaning and the use of each element in different studied done before. For more detail about the tables of synthesis review and for the detailed Table 2 which shows the criteria's, followed by a description and the source of the information refer Appendix 2.

Table 2. Pro-poor and fit-for-purpose criteria's

Pro-Poor	**Fit-for-purpose**
-Affordable for citizens & government. Transparent / Accessible / Equitable -Include Complex rights, formal tenures, customary and informal tenures and secondary rights -Build based on social tenure (Simple/ Quick) -Close to the people -No high accurate boundaries and complete data (1st stage) -Creation of simple index -Land record management as part of public administration. - Deliver justice (objective information, rights, limits, restrictions) - Co-management of pro-poor land record	-Affordable -Flexible -Inclusive -Reliable -Participatory -Attainable -Upgradeable

4.2. Land experts functional and technical requirements

This section describes the requirements retrieved from the interviews with land experts working in the field of land administration in and out of Ethiopia. The requirements of the system can be different from the requirements of the users. In the context of a country, the requirements can change from user and country context. From the different key-informant interviews were identified requirements represented in Table.3. As identified, a land professional with previous experience in data collection or implementation of mobile apps would like to have in an app the following requirements. The requirements from land experts in Ethiopia were identified during fieldwork. The design of the table is a combination of land experts out and in Ethiopia.

Requirements were analyzed and described in detail regarding their importance and their function in land administration.

Table 3. Land Professional Functional Requirements

	Land Professional Requirements	**Description**
Functional	Used for land administration processes	Can be used in different processes as: adjudication, demarcation, storage, maintenance.
	Collect person information	Name of the landholder, multi landholders, private or public.
	Collect property information	To have a identify number for the parcel, Local or global Id
	Collect spatial information	Collect points (for point base cadastre), polygons (boundaries), area, coordinates.
	Collect primary and secondary rights/restrictions	Collect all rights and restrictions related to the property
	Collect formal, informal and complex tenure	To include all types of tenure (Continuum of rights)
	Collect relation "Person-Right-Property"	Make possible the connection with relationship classes between "Person-Right-Property"
	Collect data in offline/online mode	Collect data with internet Collect data without need of internet
	Collect different type of information (text, drawing, images, voices, videos, finger scan, digital signature)	Collect text, drawings, images of boundaries or documents, collect finger scan or digital signature, videos.
	Storage the data into a safe database	Database which allows the security of collected data from loses or damage
	Cloud base options	For offline mode a cloud base option is a solution for the data management
	Allow data editing/update/recapturing	In case of errors to edit the data, in case of transactions, subdivisions, or data loses.
	Allow data visualization	Data can be visualized in different base maps, mobile, online, software
	Participatory mapping	Can be used for participatory mapping, including implementation of citizens.

Table 4. Land professional Technical Requirements

Technical	Have customized attributes	The possibility to be adapted to the needs and requirements of the country that will be used. Refers to the idea that an app can change attributes and type of data collection, adapting to the purpose and the type of information that will to be collected.
	Easily installation and use	The installation of app should be easy and the use of the app should not be complex in order to adapt to all citizens for using and understanding it.
	No limitation in quantity of data capturing/storage	No limits for the capture information in terms of quantity and no limits in data storages.
	No need for programming skills	In a way that can be used from people who do not have programming background, such as field surveyors.
	Adapt to all citizens	The people which are landholders are simple people which need to see and understand the method used in order to trust on it. Not just for professionals and experts.
	Installed in every mobile	The user can be a field surveyor, which can have a cheap android phone, or can be even a surveyor which can afford to have an iPhone. The app should be designed to be installed in all phones and operating system in order to be used form different people in different part of the world
	Different operating systems	Can be installed in different mobile operation systems such as: windows, android, iOS, or desktop.
	A multilingual mobile app	In a way that all the citizens or professionals can use it. In order to be used in different part of the world, it requires the option to choose the user language. Tenure types in most of the countries are in the local language, and most of the farmers in developing countries still do not speak English.
	Connect with extra devices	System of the app should allows extra device for improving accuracy such as external antennas, or GNSS.
	Certain level; of accuracy (decimeter)	Should give a certain accuracy for the data collected.
	Have a certain zoom level	Allows a good zoom level for better visualization of terrain during field data collection
	Give possibility for automatic update	No need for extra work to update the data from mobile into system
	Time/Cost characteristics	Low cost app and certain speed in data capturing
	Allow attachments (pictures, images)	In order to avoid copying, scanning documents. Taking photos of the Identification documents or pictures of the boundaries in case of boundary conflicts can be a good option for proof needed in cadastral data collection.
	Allows multi users	The option that multi user can use the app on the same time
	Recoding voice for people that cannot write	In future will be needed that people who cannot see can be part of the registration process; recording their voice for confirmation purpose, or for people who can not write
	Special data capturing	System which allows digital signature/ finger scan

Apart the listed elements on the table 2 and 3 the land expert express the need that the mobile app should have the legal approve of the country where it is used. This in terms of design, data management, data privacy and law requirements. In case on Ethiopia, land experts found necessary the approve from decision making institutions to implement such kind of technology.

Those results shows that requirements of land professionals outside Ethiopia and those in Ethiopia overlap. There are few elements which international land experts identified differently from land experts in Ethiopia. A international land experts requires: cloud base options, special functions from illiterate people, direct database storages, participatory mapping, improvement on data processing, customized attributes, external GNSS, adapt to all citizens, no need for programming skills, different operation systems, no limitation is data storages. What land experts in Ethiopia require are the main information for land administration, and what can be specifically mentioned different from international experts requirements are : Approval of the government, way to implement signatures and finger prints and a focus of them was accuracy. Those data reveal that the requirements for implementing an app into the cadastral system are mostly the same with small differences in specific countries.

5. APP SELECTION

This chapter includes the major information related directly to the apps. An explanation about the three-stages of pre-selection was done. It provides a list of apps available on the market that enable spatial data collection.. In addition, the actual steps followed and results, for the selection of the app, are provided.

5.1. Apps available for collection of geographic spatial information

The market has brought a new trend: the possibility to choose an app that is more adaptable for the purpose of its use. There is quite a considerable number of apps on the market and for a user that is willing to select an app for collecting spatial data, the first questions that comes up is: Which one? In total 30 apps for the collection of spatial data were identified. Taking into consideration that this is a considerable number of apps, some pre-selection steps were followed: pro-poor & fit-for-purpose requirements/criteria's were used, as well as the requirement that an app should align with the preferences of land professionals. For the complete list of apps and their characteristics see Appendix 3.

5.2. Pre-selection of apps

The information about the apps was retrieved from different sources of information: internet, literature and in 2 previous projects done in ITC from students during years. Taking into consideration a large number of apps on the market, a three-stage process was used to come up with a list of apps that can be used for cadastral data collection: 1. Spatial data type; 2. Costs of the app; 3. Operating systems. The first stage excluded apps which do not offer the possibilities to collect spatial data as polygons, lines or points. The second stage excluded apps with a cost higher than 10 Euros per month. The third stage excluded apps which have just 1 operating system (desktop, iOS, Android).
Table 5. shows the 30 identified apps color coded based on their selection stage: red for the first stage, orange for the second stage, yellow for the third stage and with green the accepted apps.

Table 5. Identified apps available on market

3D GIS	**ArcGIS**	**ArcPAD ESRI**	**Collector for ArcGIS**	**CyberTracer**	**DataPoint**
Field Tracer	**Fulcrum**	**GeoODK Collect**	**Geo-Wiki**	**GIS Kit**	**GIS Pro**
GISRoam	**GPSEssentials**	**IGIS**	**Integrity GIS**	**Locus Free**	**MapGo GIS Data Collection**
MapIt-GPS Data Collector	**MAST Application Suite**	**Mobile Data Collection**	**Mobile GIS (GIS2GO)**	**My maps**	**Open Tenure**
Pocket Earth	**Point GIS**	**SuperSurv**	SuperSurv M3--GPS Plug-in	**View Ranger**	**Wolf-GIS**

Excluded 1st phase | Excluded 2nd phase | Excluded 3d phase | Accepted

Collector for ArcGIS - a mobile app developed by ESRI for the collection of spatial information, and for update information with or without the need of internet connection. The app is designed to use your own map, to link with an external device for better accuracy, capture of photos and improve data quality (ESRI, 2015).
GeoODK Collect - a mobile app that was derived from Open Data Kit for collecting and storing geo-referenced information ("GeoODK," 2014). It is an open source platform created to fulfill the future needs of data.
Locus Free - a multifunctional application that can be used in different fields and for different purposes. It allows offline and online data collections, points, lines, polygons with or without GPS ("Locus Map - Mobile Outdoor Navigation App," 2014).
MapIt-GPS Data Collector - a mobile app designed for land surveyors to collect GIS data. It gives the possibility to calculate areas, distances and supports every kind of GPS data collection, to share and export data in different formats ("Map It - GPS Surveys Collector," 2015). It gives the possibility to have an extra extension to you basic app for different purposes, to create offline maps and generate your own map on the app (mapitGIS, 2015).
MAST Application Suite - a mobile app that was developed with the purpose to capture land rights information and cloud data management infrastructure. Mobile Application to Secure Tenure was piloted on Tanzania for identifying the boundaries of the parcels, for collecting demographic and tenure information for several villages (USAID, 2015b).
Open Tenure - is an open source app developed with the support of FAO for the collection of information about land tenure and data registration for poor countries (Pullar et al., 2012).

SuperSurv - a mobile app designed with an integrating GIS and GPS for collecting and surveying of spatial data. The app includes data collection, orientation, map display and with the ability to represent all type of features as a point, line, polygons even in offline mode and suitable for the global coordinate system (Supergeo, 2015).

5.3. Technical Comparison of Apps

A comparison of the apps was done based on the technical and functional requirements needed for cadastral data collection. This comparison (Table 5) was done based on criteria's of pro-poor and fit-for-purpose (Table 2), moreover on the requirements identified (Table 3 and 4) from the land experts interviews.

Those identified requirements include: the selected app should be accessible for all users, to afford all type of data collections (point, line, polygon), to have different type of data format (SHP, KML, CSV), be used for different processes (collection, visualization, storages), no need for programming skills, to allow based layer (orthophotos, satellite imagery, free base layers), to have different languages, to be installed in different operating systems, used offline/online, to allow storage database, capture extra data (pictures, recording), capture coordinates based on coordinate systems, no need for training, allow external device as GNSS, and what is more important to allow customized attributes. The 7 accepted apps have very similar characteristics to be used for cadastral data collection, but the collector of ArcGIS was more familiar and the access to support was one of the main reasons for this selection.

Table 6. Technical Comparison of Apps

	Collector for ArcGIS	**GeoODK Collect**	**Locus Free**	**MapIt-GPS Data Collector**	**MAST Application Suite**	**Open Tenure**	**SuperSurv**
Version	10.3			3.3.5		1.2	3.2
Operating Systems	iOS, Android , Windows	-	iOS, Android	Android	-	iOS, Android	iOS, Android
Cost	Free	Free	Open Source	Free	Free	Free	Free
Language	Multi-lingual				English	Multi-lingual	
Online mode	√	√	√	√	√	√	√
Offline mode	√	√	√	√	√	√	√
Customized Possibilities	√	X	X	√	X	X	X
Base Layer	√	X	√	√	√	√	√
Programming Skills	X	√	X	??	√	X	X
Export Data formats	**GPX, CSV,KML,WMS,SHP**	-	**KML, KMZ, GPX..**	**CSV, KML, GeoJSON, GPX, DXF**	-	-	**SHP, KML, CSV, GEO, SHP**
Import/export possibilities	√	√	√	√	√	√	√
Storage Database	√	√	X	X	X	√	X
Bluetooth	√	X	X	X	X	X	X
External Devices	√	√	X	X	X	X	X
Capturing pictures	√	-	√	√	√	√	√
Speed of capturing coordinates	Customized	Customized	Customized	Customized	Customized	Customized	Customized
Coordinate System	WGS84	WGS84	WGS84	Global/local	Global	WGS84	Global/Local
Accuracy	Relative	Relative	Relative	Relative	Relative	Relative	Relative
Need for training	X	X	X	X	X	X	X
Online Account needed	√	√	X	X	X	√	X

5.4. Collector for ArcGIS

The selected app was Collector for ArcGIS. The design of collector was made years ago by ESRI. After different tests on the field, and with the improvement of technology, the app was updated to a new version in 2015 that allows the users to make a customized app.

The app can operate in different systems as: Android, iOS, desktops and windows phone/desktop, available in 28 different languages. It can be found in mobile markets as: Play Store, Apple Store or online on the internet, from where can be downloaded for free. There are 2 options available for using the app: a trial version for 30 days where the attributes are already defined by the developer or the customized attributes which can be defined by the user and need an ArcGIS account.

The app has the option for offline and online data collection. An option which supports data collection in poor countries and worldwide areas, where the coverage of internet is missing completely or in the case where coverage is slow and costly. The offline mode data collection offers the possibility to collect data without the need of the internet or mobile network. The data is collected and will be on the cloud up to the moment that the user updates them. The app has an option "sync" which allow you to update all data collected in the field directly to ArcGIS online and, later on, proceed with data analyzes and visualization.

Even though the variety of mobile apps none of them, except Collector for ArcGIS, gives the possibility to define your own attributes without having programming skills. In Collector for ArcGIS, it is easy to select and define your attributes, in order to collect all types of necessary data in land administration.

Another good possibility is to have a base layer for free directly from the internet, or in case the base layer doesn't have full information about the area of interest, can be imported an orthophoto or a satellite imagery directly on the app and can be used as base layer during data collection.

After data collection, there is the possibility to store the data or to download the data on desktop in different formats including GPX, CSV, KML, WMS, and SHP.

The unique functions of the app, which highly influences the selection, was the possibility to connect an external device as GNSS via Bluetooth, for retrieving coordinates with a higher accuracy compared to other apps which are on the market. The needed course for access the Collector for ArcGIS are ESRI organization account, pc with ArcGIS Desktop, internet and a mobile.

The steps followed from the download of the app up to the last process of visualization are described in detail in Appendix 4.

5.5. R1 GNSS

The design of the app Collector for ArcGIS is done to support a device which can be connected with the app via Bluetooth. The extra device, retrieving correction signal from satellite reduces errors that affect measurements. In this way the measurement should be of an accuracy of decimeter.

R1 is designed by Trimble, the idea of the R1 is to get correction signal with tracking satellites on the sky and then with an L-band (Appendix 5) the signal on the mobile is reduced from errors as atmospheric errors, satellite clock errors and multipath. R1 can afford correction as SBAS, VRS, RTX(via internet), RTX(via satellite) or uncorrected.

The connection of the R1 with the mobile need an app called GNSS STATUS UTILITY. The app can be downloaded for free on the mobile, allows the connection of R1 with the mobile. With the help of the app is possible to select the options favorable for the area where the measurements will take place. The status utility works without the need of internet, just in case the correction signal is via internet then an internet connection is required. The status utility gives on real time the accuracy in units that user defines.

To summarized this chapter: the apps that can be used for cadastral data collection are 7. Those apps fulfill the majority of user requirements and criteria's for pro-poor and fit-for-purpose. The selected app for the field was Collector for ArcGIS linked with a GNSS device called R1.

6. ADAPTING AND APPLYING THE APP FOR ETHIOPIA

This chapter focuses on designing, adapting and applying a new cadastral data collection with the use of Collector for ArcGIS. Results are designed during fieldwork, where the mobile app was tested the mobile app. This chapter is used to visualize the design of necessary steps for embedding a mobile app into cadastral data collection, and for comparison of spatial information with the actual data collection process in Ethiopia. A design of workflows was done in collaboration with land experts of woreda office in Bahir Dar Zuria.

6.1. Adaption of mobile app for cadastral data collection in Ethiopia

To make possible a collection process three steps are needed to adapt the Collector for ArcGIS for offline data collection (Figure 5).

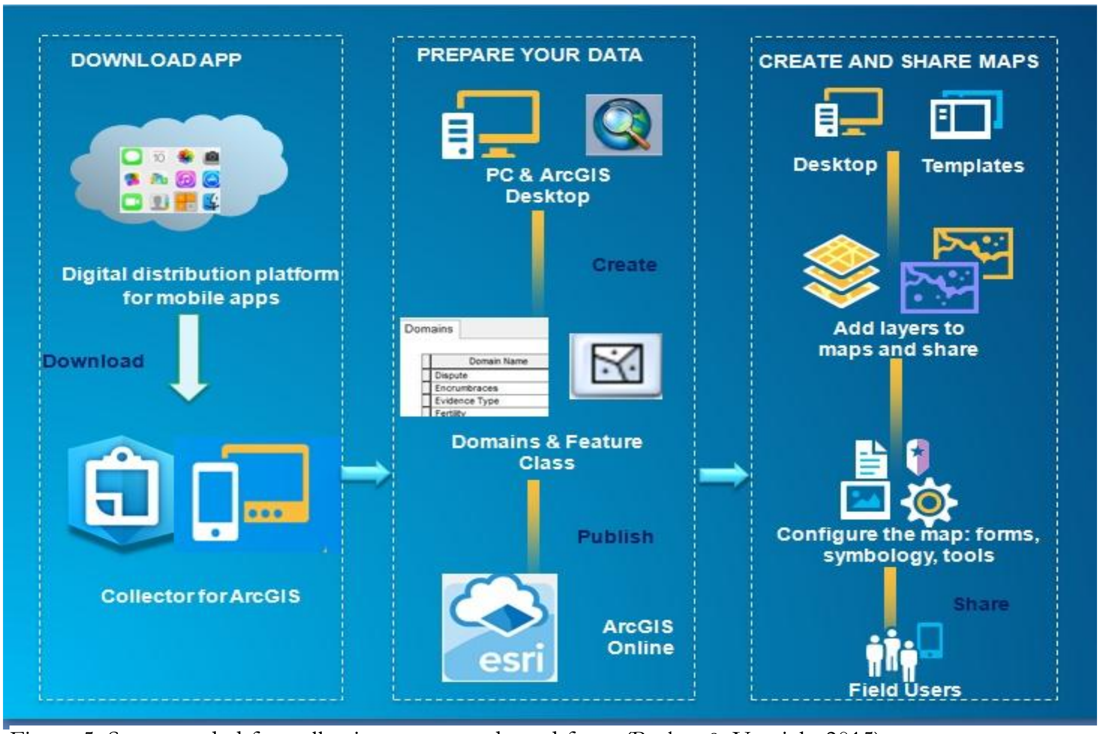

Figure 5. Steps needed for collection process adapted from (Barker & Yagrich, 2015)

Firstly, the mobile app should be downloaded from a digital distribution platform for mobile apps such as: Apple Store or Play Store. To continue with the data preparation, where the creation of the domains and features based on attributes needed for data collection should be done. The feature classes properties can be created by following the trials of ArcGIS online. The creation of feature classes needs resources like computer, internet connection, ArcGIS Online account and ArcGIS for Desktop. A simple process, fast which makes possible the connection between person data, right data, and property data with the 1-M relation between class properties. The attributes (Appendix 7) were defined based on the field form (Appendix 6) for cadastral data collection in Ethiopia. Another option of the Collector, can be direct connection of the required attributes into a database. Moreover, a base map from ESRI base maps, or an orthophoto or a satellite image can be inserted. Finally, for offline data use the map should be downloaded directly into the device, and the user can collect data.

6.2. Developing a new cadastral data collection process based around apps

In a way to embed a mobile app into a cadastral system four main stages were identified: Preparation stage, Planning of data collection, Data collection and Data management (Figure 6).

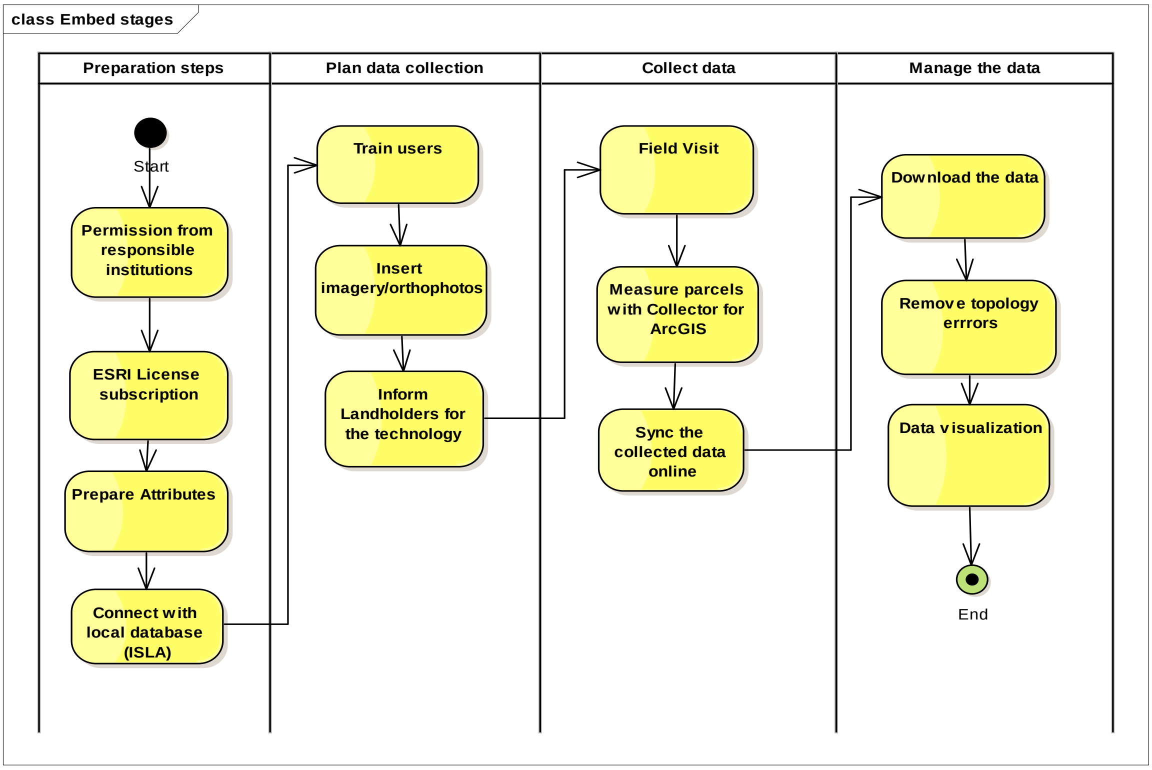

Figure 6. Stages for embedded of app into cadastral data collection

Preparation stage includes the necessary permissions from the institutions responsible for decision making for cadastral methodology. The use of the Collector for ArcGIS has restrictions on using ESRI license, so a subscription for a long period of time is required. Moreover, the design of the app attributes should be done based on the system requirements (Field Form). Also, a connection with local or national databases can be made.

In the second stage, Planning of data collection, a short training is needed for the surveyors and digitizers, explaining the functionalities and responsibilities. The Collector for ArcGIS allows the use of imagery or external images for your app, so those images should be inserted in the mobile phone or should be available for download online. The last step is to inform the landholder for the changes in technology. This should be done so that the landholder understands and accepts the data collection.

The third stage, Data collection, is the stage where the data are collected. For making possible, the collection process a field visit for measuring parcel boundaries is needed. The measurement of boundaries is done by going around the parcel and collecting the data directly on mobile. Coordinates are captured by LBS. After data collection is completed, the user can "sync" to update the data collected from the field in ArcGIS Online.

The last stage, Management of data, is office work. The data can be downloaded and the digitizer can edit, check topology errors and can update them directly in the database. The visualization of the parcel boundaries and specific information can be done from ArcGIS desktop or directly from ArcGIS online.

6.3. Testing a new cadastral data collection process with Collector for ArcGIS

In order to make possible the testing process of the mobile app in Ethiopia, Amhara region a UML diagram (Figure 7) was designed to show the steps and users involved in cadastral collection process
From the design the steps and users who were considered extra and unnecessary in the actual cadastral data collection in Ethiopia were excluded. Compared to the UML activity diagram (Appendix 8) of current cadastral data collection, the use of the mobile app for data collection requires less human power and fewer processes for the collection process.

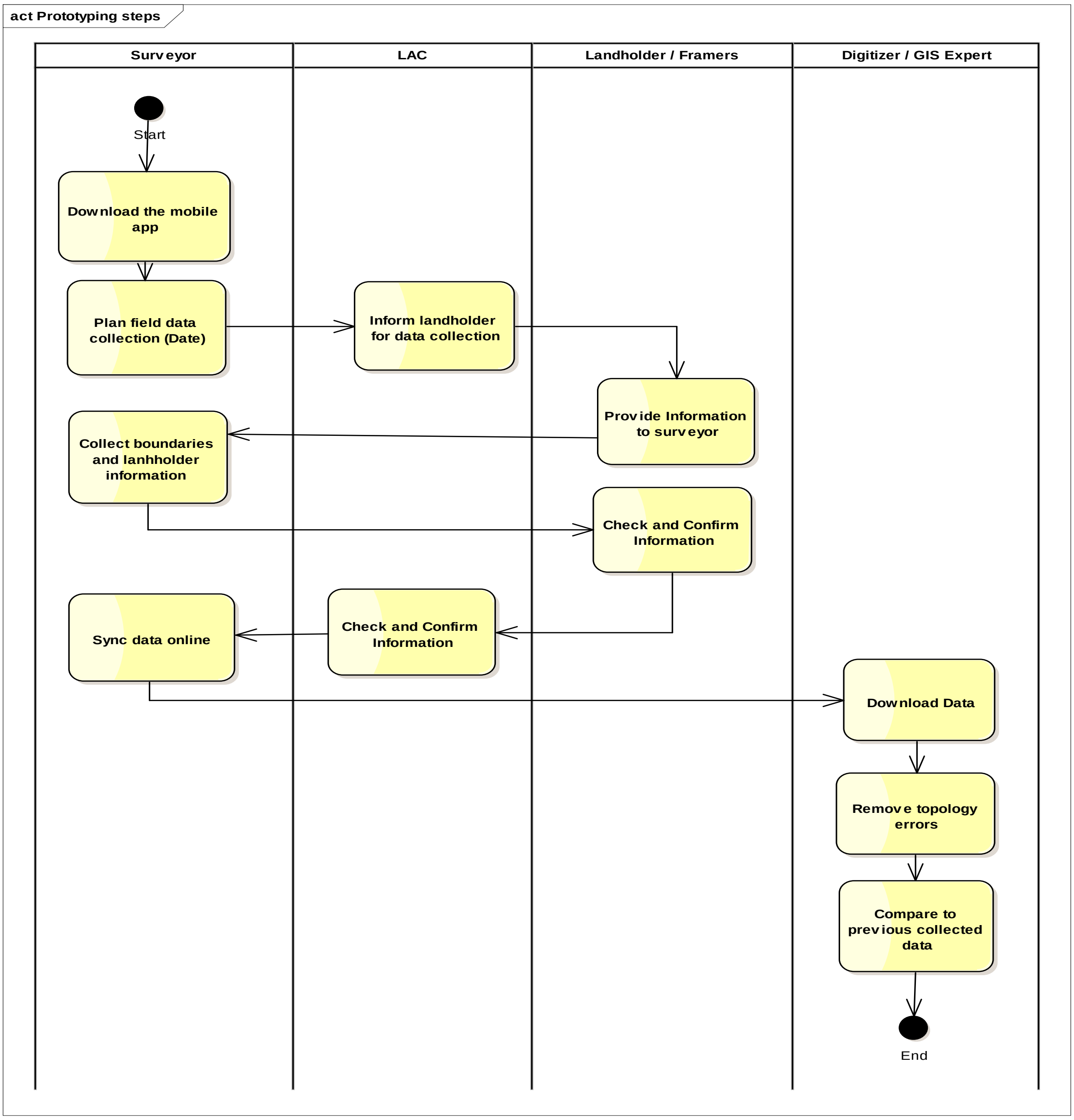

Figure 7. Steps for prototyping a new collection process

The collection process with Collector for ArcGIS was done in collaboration with the field team in the Feres Woga kebele. Collector for ArcGIS tested in the field gave the possibility to collect the majority of the data needed for cadastral data collection. The data collection was done connected with external GNSS, R1 of Trimble, combined with the GNSS Utility (Figure 8) app for retrieving the correction signal.

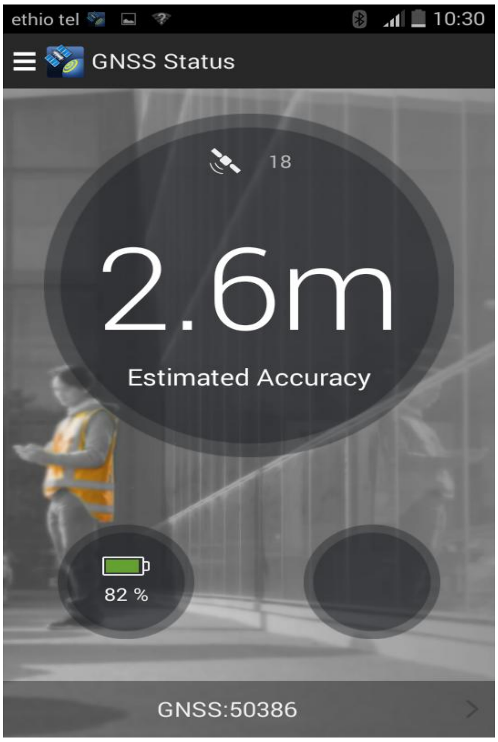

Figure 8.Screenshot of GNSS Status during data collection

Figure 9. Screenshot of Collector For ArcGIS during data collection

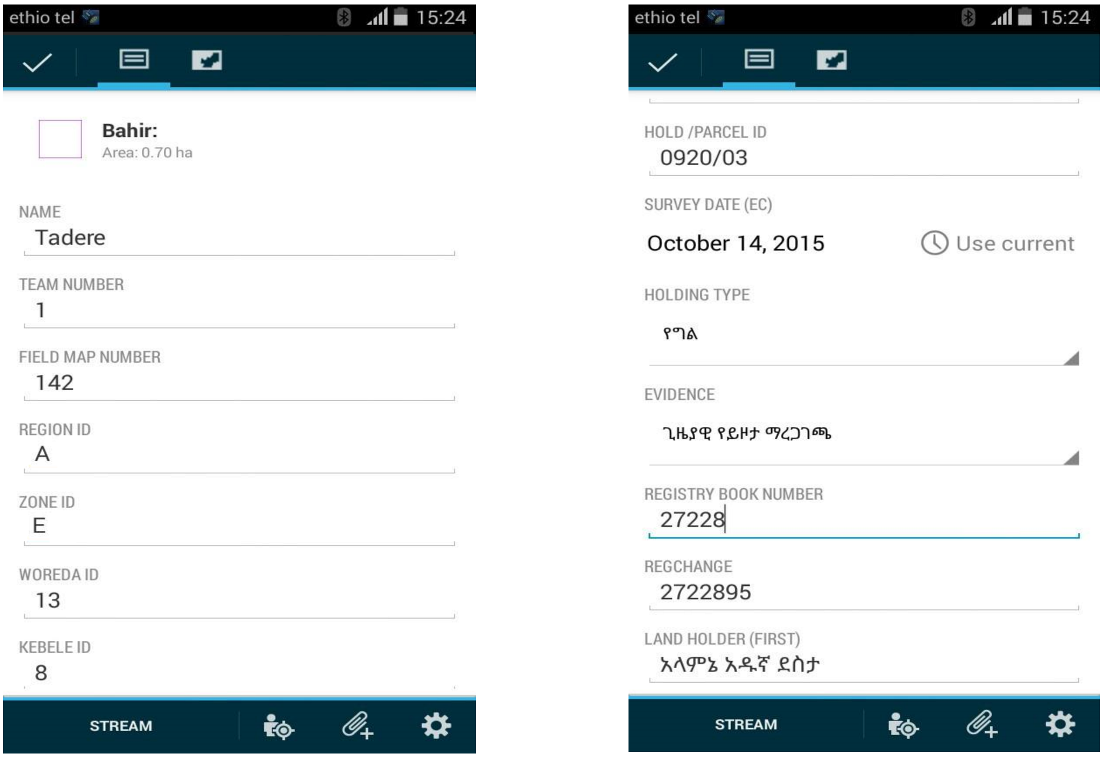

Figure 10. Screenshot of attributes collected with Collector for ArcGIS

The GNSS Utility status gives the option to visualize real time accuracy, the correction signal and the satellite available in the moment of data capturing,. For collecting parcel boundaries, it is required to go around the parcel and collect different points using the LBS. The visualization of parcels collected during fieldwork is visualized in Figure 9.
Apart the spatial information, other information necessary for the second registration in Ethiopia such as land tenures, land use, and landholder information was collected (Figure 10). The full list of attributes (Appendix 7), were defined before collection and managed to be created in Amharic, a element that makes the field surveyors very comfortable during data collection.
Moreover, the collection of pictures made possible to reduce the time needed for collecting information. The photos of the landholders, green book, boundaries were attached to specific parcels. The visualization of the collected data can be done in 2 ways: directly on ArcGIS Online or downloading the data and visualizing on the ArcGIS Desktop (Figure 13).

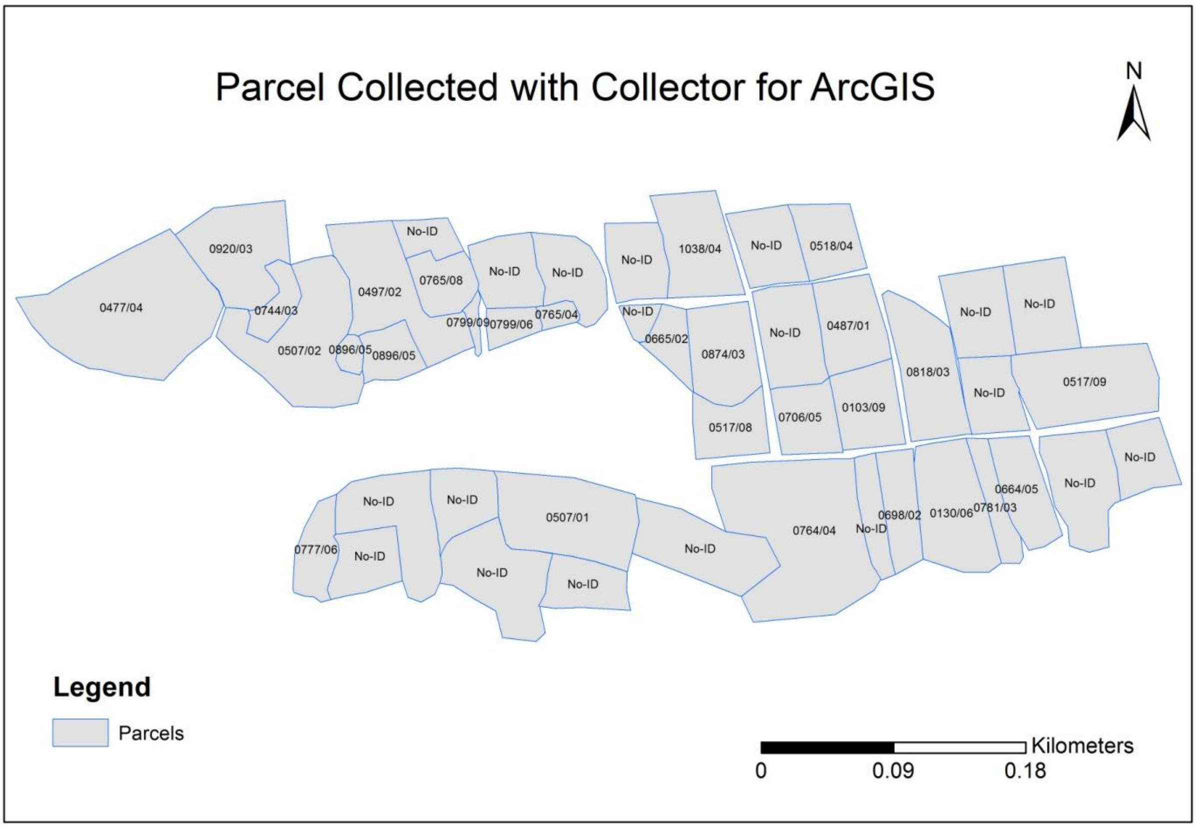

Figure 11. Map with collected parcels (Own creation)

The steps undertaken for adapting, designing and testing Collector for ArcGIS were not difficult or complex. Following the instructions from ArcGIS Online, it was a simple process for data creation, preparation and collection. The majority of the difficulties were faced during data processing, due to the high number of topology errors. The errors were cause of uncorrected signal from satellite. As the fact that during field work it was impossible to get a correction to make the measurements, in Feres Woga, the measurements were done with the GNSS and a post processing was done for receiving the exact coordinates.

6.4. Differences in data from current cadastral collection process

The actual data collection consists on pencil and paper collection method. The process of collection is done by the team of field data (para-surveyor, field recorder, team leader, LAC member). The surveyor draws the boundaries over the printed orthophoto, later on, the boundaries are re-drawn with a pen so that the lines can be visible in the scanner. The digitizer scans, georeferences and digitizes the parcel boundaries. In the end, the information collected in the field forms in entered manually.
The same procedure was done for the comparison purposes. The field maps were scanned, georeferenced and parcels were digitized. For comparison purpose, the digitized parcels were overlapped with the collected parcels (Appendix 9). A comparison, between collected parcels and digitized parcels, about the derivation in the perimeter and area, was done. In total 42 parcels from 47 collected were compared. There were four excluded parcels which were not digitized for the reason that boundaries were out off the field map and one parcel which was collected with different boundaries from the digitized one.

Table 7 shows the percentage of parcels which results with changes in perimeter. From 42 parcels, 86% were having <1 % difference in perimeter. With a percentage of 1-3% there were just 5 parcels, (12%) from the collected parcels, and with >5% was only 1 parcel (2%). There was not any parcel between 3-5%. As it is visualized in (Table 7) results show a high percentage of the collected parcels not having differences bigger than 1% in perimeter

Table 7. Differences in perimeter

%	Number of parcels	Percentage
<1	36	86%
1-3	5	12%
3-5	0	0%
>5	1	2%
Total	42	100%

Table 8. shows the percentages of parcels for the change in terms of area. With <1% difference, 17 parcels (40%) were found; with a percentage of difference from 1-3% 20 parcels (48%) were found; Parcels with difference from 3-5 were 12% concluding with no parcel with change in area of more than 5%.

Table 8. Differences in area

%	Number of parcels	Percentage
<1	17	40%
1-3	20	48%
3-5	5	12%
>5	0	0%
Total	42	100%

From the above tables it can be stated that the differences in collecting spatial data with both methods are not very high. The perimeter of the boundaries (of 2 data collections methods) overlaps with more than 86%. Still there is a different result from the area calculation where the percentage of difference is higher for 1-3% in 20 parcels (48 %). Similar results have been developed even from comparison of data collected with Total Station and High Resolution Imagery from (Yagol, Shrestha, Thapa, Poudel, & Bhatta, 2015). This shows that there is not a big differences in data between mobile apps and high resolution imagery. Moreover, these statistics show that mobile app does not have drastic changes from the actual method used in Ethiopia.

Most of the boundaries overlap but difference in the area is noticed. The higher differences in the area can be due to different errors affecting the collection process. Differences in shape or boundaries can be caused by terrain, high vegetation, the field track, density of points and GNSS correction signal. Other errors can be made during the drawing of the boundaries, or digitizing process. All the mentioned errors give the differences in the shape and area.

Apart the differences in spatial information, there were few differences in the other attributes. The parcel collected with mobile has the same attributes collected with the current method.
Other differences of the new method with the current one, are the number of actors and processes involved in the collection process. The majority of difference is on the steps followed from collection up to the certificate data visualization. The device of mobile is light and can be carried in the pocket while the paper-based forms can be damaged, and sometimes the handwriting is unreadable.

6.5. Limitations/ difficulties with the app

The process of data collection and data processing had different difficulties in capturing, editing and visualizing. The mobile app gave the possibility to collect all type of data except 2: finger print and digitized signature. In Ethiopia, the landholder, team leader, and LAC member need to sign the field form to confirm that the collected information is correct. This was a requirement in the law for which the app showed a shortage in data collection.

The mobile app offers to the user the option of the capturing picture. During field work, different pictures were captured such as landholder, registry book, and boundaries. The pictures could be download directly from the ArcGIS Online, by clicking over one specific parcel it was possible to check all the data and to see the attachments. To have the picture of the attribute tables and connect them with the specific parcel it was not managed. The pictures were downloaded from ArcGIS Online manually and then linked with the parcels in the table of attributes.

The collection process was followed with some errors in data collection. Those errors were due to the finger size. It was difficult on the field to assign by finger the point for the position, because the icon of the point position was small compared to the finger size. Multi-click on the map or multi-points in the same position were common errors. This strained on repeating the measurements for some parcels.

Despite the fact that the area could be calculated directly from the field, the attribute of the area was not filled automatically. The user should calculate the area in ArcGIS or type it during data collection.

The architecture of the apps gives the possibility of using extra maps, or base maps downloaded directly from the web. The resolution of those base maps for the developing areas such as Ethiopia was very small and outdated feature information. This brings the need for having satellite images or orthophotos during field data collection which are difficult to be found. The good satellite imagery are costly and for orthophotos an aerial photography should be done.

7. EVALUATION AND DICUSSIONS

This chapter aims to represent the expected results from sub-objective 4 of this research. It focuses on users evaluation for the app and users evaluation for the methodologies. Firstly, a list of users in Ethiopia is represented. Secondly, it analyzes users satisfaction based on: data collected, interviews, group discussions, workshops, questionnaires and moreover referring to criteria's and requirements the app should have. To continue, a brief analyzes was made regarding time and cost of the apps compared with the cost of the actual system. Furthermore, the comparison between conventional methods with the new one based on the field work test is provided in this chapter. In the end, of the chapter a discussion is presented analyzing previous work that was taken into consideration in the literature review.

7.1. Users in Ethiopia and their role on the process

The users in Ethiopia are firstly field users, the professionals, or experts collecting data from the terrain. Secondly, are the users working in woreda office and finally the users working in BoEPLAU involved in the collection process and users in decision making. These users evaluated the methodology and the mobile app.

There are 3 main levels of the registration process. For each level, there are a certain number of land experts. The users were categorized into:

- BoEPLAU land experts (Zonal administration)
- Woreda office experts (Zonal department)
- Field data collectors (Woreda)

Zonal administration has 40 experts at the bureau level. This number includes land registration experts, land administration experts, valuation experts, legal experts, GIS experts, ICT experts and the surveyors. Zonal department has around 7-8 experts. In the woreda level where are managed land administration and use processes, there are 7-15 experts. In kebele, there is not an expert but a peasant association expert who trains the farmers for solving conflicts and use of the land.

Land experts in the zonal administration are involved in the phase of preparation of the registration, in filed plan and management of the process of registration. The GIS experts are responsible for the digital data, management of orthophotos, inserting, and data editing. Land registration experts and land administration process are responsible for the selection of the kebele and for administrating the whole process. ICT experts are responsible for the maintenance of the database ISLA. Surveyors are responsible for defining the ground control points before aerial photography. Land registration experts with GIS experts from zonal administration train the field experts, digitizers, GIS experts at woreda level.

Field teams are organized as this: the surveyor is the person who draws the lines; field data recorder that uses the registration form (Appendix 5) to write down the whole information, checking documents as green book, information on the green book, land use, so he confirms all the information from the landholder and write it down; major representative of land administration and committee member (LAC) which is most often a person living in the community, knowing the people, is legal representative of the landholders; team leader which checks if the parcel is correctly drawn, did the recorder write down the whole information and finally signs the registration form.

Woreda has the responsibility to analyze and enter the data from analog to digital. In Bahir Dar Zuria woreda office there were: 4 digitizers which enter the data from field form in the computer, digitizes the parcel and link the spatial data with alphabetic data; 6 land use experts who analyze the soil type, see topography and give suggestion to the farmers about land development in order that the land can be more productive; 6 land holding experts who are transaction expert, recording expert, evaluation, law/dispute expert; 2 surveyors for data measurements. In the process of data collection, Figure 9 are involved 4 surveyors, 4 land experts, 2 team leaders and LAC member which is the legal representative of the local community.

The actors involved in Ethiopia are different in their role and responsibilities. This information could partially explain the selection of the users who were the main source for the evaluation of the app and method. From the users mentioned above the users who are affected directly by the implementation of a mobile app are revealed.

- Field Team: Surveyors, land experts, team leaders and LAC member
- Woreda team: digitizers, GIS expert
- Regional Bureau: Land registration process, land administration experts, GIS experts, ICT.

7.2. User evaluation for the mobile app and methodology

For the evaluation process, the data was analyzed from interviews, questionnaires and group discussion conducted during fieldwork. Referring to the materials analyzed from the conducted interviews can be said that: from 30 functional and technical requirements identified with land experts the mobile app fulfills 27 of them. The mobile app offers the option of capturing the necessary data and has extra functions which in their perception are needed for improving not only cadastral data capturing but will be an improvement in methodology, processes, and land management.

Beyond common requirements, what was identified as innovative characteristics from users in Ethiopia was: direct connection with the database. Moreover, elements such as direct data collection into mobile, capturing of pictures, avoiding digitizing, working offline were elements which make the app more practical and more completed as a tool to be implemented into a cadastral registration process. Removing the digitizing process in their perception is the best characteristic of this method. The landholder expects that a new tool which should be implemented into the cadastral process should be used for the complete processes of Adjudication, demarcation, registration and maintenance.

From the group discussion conducted during fieldwork the advantages and disadvantages of the new method tested in Ethiopia (Mobile app) and current approach in Ethiopia were identified (Table 9).

Table 9. Advantages and Disadvantages of mobile app

Advantages	Disadvantages
Simple	ArcGIS account
Map on your mobile	Accuracy (GNSS corrections)
Avoid paper based	Topology errors
Avoid tape/GPS measurements	Battery on the field
Avoid digitizing	Cost of equipments (software, mobile, GNSS)
Records with photos	Capturing finger and signature
Direct connect with database	
Reduce time/cost	
Reduces of processes	
No need for experts on the field	

Firstly, the idea and the method was impressive to most of them. They found it practical for field data capture and easy to use. It offers the possibility to collect everything such as rights, boundaries, coordinates, pictures connected to an external device and take notes directly on the app.

Secondly, compared to the actual method the mobile app offers the possibility to capture images. This element was identified as an additional characteristic which allows the field collector to take a picture of the parcels boundaries, pictures of the documents showing or even of the farmers in itself. An original element which can be the next step for Ethiopian cadastre.

Although the land professionals focus more on the characteristics of the app, and they were supporting this idea, there were even question marks regarding the app. They concentrate on reducing cost as much as possible, and their idea was that majority of the cost is reduced by using QGis. They found the restriction of using ArcGIS for the app a question mark which can affect the implementation of this mobile app into cadastral systems. The reasons were based on the cost of ArcGIS, and the willing of the Ethiopian government to accept changes from open software to paid one.

Based on the land professionals opinion, in Ethiopia the accuracy is outstanding. From carried interviews was identified that each person has a different opinion about the boundary accuracy of the plots. From interviews, different answers were given, as for private parcels an accuracy of +/- 1 meter or +/-2 meters, for government land +/- 5 meters.

To understand the differences and improvements in the methods were identified the main difficulties land experts are facing during the second registration phase. Table 10 represent the list of advantages and disadvantages identified from interviews with land experts in Ethiopia.

Table 10. Advantages and Disadvantages of current method in Ethiopia

Advantages	**Disadvantages**
Cost-effective Fast data capturing Participatory Simple No experts needed on the field Proper for Ethiopia case	Slow process Paper based forms Printing costs Extra measurements for GCP Rectifications problems Tape and GPS measurements for invisible boundaries Registration in mountains area not yet planned

After all other methods tested in the field, the actual method is seen from the land professionals as the proper one for the moment. It is simple and the cheapest that can make possible the registration process. As one of the land professionals expressed himself about the selected method: "*we do not have the technology, we don't have the experts so we select simple, participatory and cost-effective approaches*".

Land experts find the actual method easy because there was no need for expensive equipment and did not need experts for field data collection. Is cheaper and faster compared to methods such as GPS or total station. Compared to satellite image they found more easy because satellite imagery needs more trained people and has many problems for a topographic terrain as in Ethiopia.

In the same time, they face difficulties with the human power. The financing for printing the orthophotos still lacked because this was not covered by the budget from the beginning of the process. The need for creating reference points and rectification were mentioned as the biggest problem they had for the moment. Still it was not yet decided for the mountain areas where the use of orthophotos was not always best solution because of the v-shaped valleys which in the measurements will bring considerable errors in the area of the parcels. The main issue Ethiopia government was facing were not financial problems but the time. The need for fast registration was essential for the farmers, for investors, for the government, for the land reform. The slow going process requires new tools to improve the speed of the registration process.

From the questionnaires conducted, a question focus on the user opinion regarding the app from the perspective of time reducing. From 10 questionnaires, all of them answered with YES, the app reduces time. The fact that reduces time, digitizing and human resources they agreed with the fact that reduces costs too.
Furthermore, from the questionnaires were identified the opinion of the users for implementing a mobile app into cadastral data collection, elements they like from the mobile app, elements they did not like from the mobile app and, in the end, their opinion about the completeness of second registration in time with the actual method. Down are represented the main answer from the carried questionnaires.

Opinion of the users for implementing a mobile app into cadastral data collection
"As part of the development of the cadastral mapping process, it is potentially very important"
"In my opinion applying apps to cadastral data collection is very promising and usable for Ethiopian case as it keeps its accurate at the level of fit-for-purpose"
"It is promising study especially in identifying some specific limitation we have here in Africa"
"It is a good start but demands further investigations and study on the improvement of the accuracy, for invisible parcel boundaries"

Elements users liked about mobile app.

"Easy to use, greatly reduce office work, multiple information can be stored, clear confirmation already on the field of what has been mapped"
"Simplicity, flexibility, adoptability"
"Reduce time for data collection"
"Innovative and needed "

Elements users did not like about mobile app

" Accurate image digitizing need a high zoom, which slows down the digitizing, storing images in the database takes much space. -measurements problem in forests and with borders demarcated with trees -uncertainty in receivers of corrections -readability in direct sunlight for some devices"
"Accuracy level"
"Accuracy need improvement"
"Open source tools are a focus of our government, GIS is very expensive for poor countries as Ethiopia. We focus in reducing costs"

After testing the app with one of the land officers his expression was: *"About the app is a need for us. We are going to issue second level registration, with orthophoto, and need of digitizing so many activities, so if it is successful we will be lucky. "*

Opinion of users about the completeness of second registration in time with the actual methods.

"Even with the current speed the registration process will take many years, so any improved methodology is very welcome"
"It is difficult to say this because it is really hope process and work and it requires a lot of resources to complete but I think we do not finish on time"
"I hope so"
"I don' think so, but hoping that better and faster methods will be derived in the future"
" Is too ambitious plan. I think will take more than was predicted"

The questionnaires conducted with the field worked team showed that 4 of the experts who try to capture data with a mobile app and complete the questionnaires found the use of Collector for ArcGIS easy. They evaluate the app with "Good" and "Excellent". All of them responded to the question if they will choose the mobile app or the paper-based form for data collection response that they will choose the mobile app. They found it faster compared with the actual process. Differences in numbers of parcels collected with a mobile app and with paper-based were small since the parcels which were collected with the mobile app were based on the parcels field team planned to collect in those days. There were not responders who found the use of mobile app difficult. They could not capture all the information of the field maps (fingerprints and digital signature).
One of the responders found the process of data capturing (going around parcel boundaries) tired and time-consuming. Two of responders considered the problem of fingers as the biggest problem. Just one of responders raised the idea of the need for training to understand how to download the app, to use the mobile in the field and manage the data.

7.3. Time and Cost of the methodologies

From land experts, the interview revealed the information for the speed and cost of the actual method in Ethiopia. The reasons why the current land registration is not on the required speed and what are the financial issues they have faced.

The full registration of the first kebele needed 1 year. Actually, one kebele needs a few months due to the experience gained. It is supposed that a para-surveyor in the team can collect up to 120 parcels per day, but due to different factors as: the presence of the landholders on the field during registration, missing of documentation, climate condition, the process in itself are factors which increase the time needed for data collection. Another factor affecting the time are the steps followed to make possible the registration of the parcels. Scanning and digitizing, as was mentioned in the previous chapter, are very time-consuming. It was supposed that a digitizer can do minimum 40 parcels per day.

On contrary from the time the cost of the process is not facing significant issues. There is no a published study related to the cost of the second registration. The cost of the orthophotos was covered by the government. One of the projects which are involved in the registration process in Ethiopia, made a calculation about the cost of the system in Ethiopia, and they come to the result that actual registration process in Ethiopia is estimated to cost 8.4 $ per parcel. From the information retrieved during interviews, an orthophoto cost around 600 birrs per 1 square/km. The average salary of the employees who are involved in collection and registration process is around 3875 birr. The cost of printing the orthophotos is around 600 $.

In order to have an idea for the improvement in time and in cost with implementation of a mobile app the data was analyzed from interviews, questionnaires and the information collected from the costs of equipment. The land professionals agreed that that the app would reduce the time of process by removing scanning, digitizing, georeferencing, would reduce paper-based forms and the process would speed up. Ten land experts agreed that the new system will be faster compared to the actual one (Figure 15).

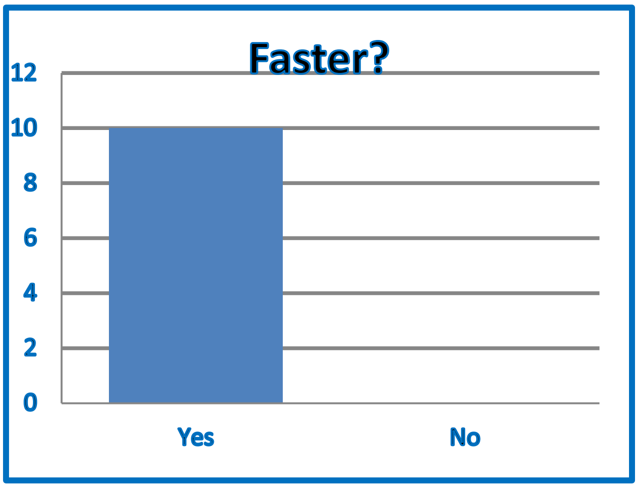

Figure 6. Bar chart- User evaluation about speed

The pie chart (Figure 16.) is a summary of the questionnaires done with the land experts in order to understand their opinion regarding the app if will be cheaper or more expensive. Half of the responders respond that the mobile app will be cheaper compared to the current method, 34% of the responders respond "unknown" and just 16% respond more expensive. They respond that reduces costs in processes but increase the costs of equipments, and some of them see this method even more costly, because changes are needed, and the process of work will change completely. From other perception, the implementation of the mobile app will be cheaper if are taken into consideration the reduction of work processes.

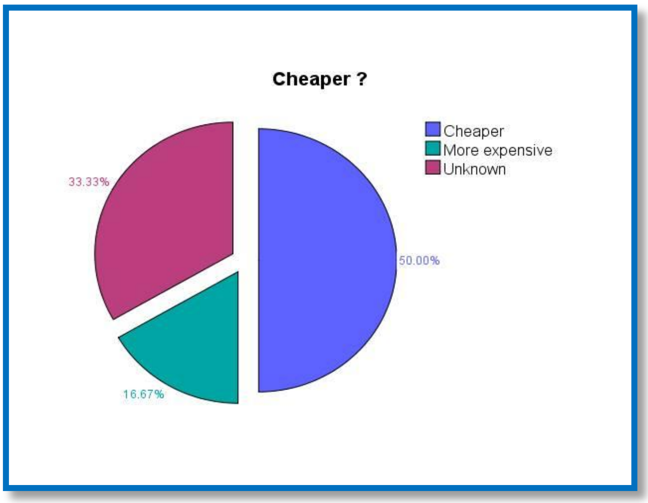

Figure 7. Pie chart- User evaluation about cost

For the purpose of the research, there were done some calculations for the cost for the GNSS (Appendix 10). It is estimated that the cost of implementing the GNSS can be around 28 cents per parcel. The calculation was done based on the plan that Ethiopian government compiled, to complete the registration in 5 years. In order to collect 50 000 000 of parcels in 5 years means that per year should be registered 10 000 000 million. The cost of GNSS was estimated to be 28 cents per parcel.

The extra cost which differs from the actual process are: The cost of GNSS device and the cost of the ArcGIS account. Taking into consideration the speed that implementation of the mobile app will cause to the system, will reduce the time in a considerable way, in this way another cost will be reduced. Actually, the costs of extra equipments can be covered just by reducing cost of ink and paper for orthophotos printing.

7.4. Improvement needed for the mobile app

From user perspective the improvement that the mobile app need are:
- Accuracy
- Special data capturing elements
- Stylus pen or improvement of point location
- Zoom level
- GNSS

The data revealed a common opinion of the users needs for accuracy. The tool should give a certain accuracy in order to be implemented in the second registration process. Despite current method is fit-for-purpose the approach the need for higher accurate data.
The improvement to be done were the elements which for the moment are missing such as digital signature and fingerprint that are required and need to be taken into consideration. Moreover, for people who do not read, who do not speak those options will be necessary for a near future.
Was proposed by the land experts was the possibility to use a pen for drawing the boundaries, Stylus pen. The pen offers the opportunity to draw precise lines over mobile screens. In case, the implementation of such technology can be costly or impossible for the moment land experts suggest an improvement of the point location of the app.
The field experience showed that field data experts found the zoom level not very high to identify the elements needed. Despite the high resolution of the orthophoto still this was a problem.
The last element which need improvement was the GNSS. The use of the GNSS should guarantee the necessary accuracy.
Those data reveal to us the main shortages of the mobile app which need further development or need an adaption in order to be implemented in countries like Ethiopia.

7.5. Discussion

The main objective of this research was to apply and evaluate an app that could be adapted to support pro-poor and fit-for-purpose land registration.

The app was selected and tested for cadastral data collection. The selected app was successful for cadastral data collection. The selection of the app did not included all the apps possible that can have the same functionaries and can be used for cadastral data collection. This choice was done with the intention to avoid the costly apps which need a specific payment for each user, in the selection of the app were excluded apps which cost more than 10 Euro per month. This may be a gap of the research excluding apps which may be better in functionalities and can be used for the same purpose as Collector for ArcGIS. The selection of the app was made taking into consideration fit-for-purpose principles, to support pro-poor ideas and based on the land experts requirements. One system fit to all is not the best choice(Enemark et al., 2014) was the idea behind the selection of Collector for ArcGIS. Not all countries need same requirements; not all states need same attributes. Firstly, from the list of 30 apps were discussed just 7 of them in detail regarding their functions. This list could be in a higher number since the number of apps which could be used for surveying, capturing or collecting data is very high but due to the time was impossible to go through all of the apps.

Referring to the founding's of (US EPA, Region 3, 2015) the selected mobile app should have some fundamental elements to handle social and scientific problems to collect geographic information, visualize them on a map, allow to integrate the information. The elements mentioned above were fulfilled from the app which gave the opportunity to collect spatial information, visualize it and the collected information could be integrated for the purpose of use. (Yavuz, 2005) called cadastral system when the legal attribute and technical attribute is associated with the spatial information. Both of those elements are characteristic of the selected app, Collector for ArcGIS. The app could create good recording system of the rights and adjudication, more was possible to make mapping and cadastral surveying, which were the responsibilities of the two cadastral systems that I. P. Williamson (1983) defined. McLaren (2014) raised the question if it is possible to collect data with the apps developed for this purpose and upload those data for free in order to be accessible from all. Collector for ArcGIS, gave the possibility that collected data in the field could be visible to the users of ESRI, this in the case when the user wants to share the data with the others, so is not a global platform used by everyone.

If the users were satisfied and what was their satisfaction regarding the app could be said that, like Ives, Olson, & Baroudi (1983) described, the satisfaction of the users based on the belief of the users about the product which should meet their expectations. Based on Chapter 4 and Chapter 7 the app meets the majority of the elements expected from users.

Steudler, Rajabifard, & Williamson (2004) aid that cadastre should be based on some principles and rules which should provide systematically trusted information about parcels which the information collected could be provided systematically and was trusted due to the fact that in collection of this information are involved professionals and gives the possibility to be used for sporadic and systematic collection. The mobile app can be used for systematic or sporadic measurements or data collection for less time and less cost. Referring to Ground surveying is better for sporadic measurements due to the time it needs and the cost. The photogrammetric are costly and still need field verification I. P. Williamson (1983).

In this research, the focus was to understand the functional and technical requirements, so the preparation requirements were not examined. The apps analyzed were a small number compared to the whole number of apps available on the market.

This research did not include crowdsourcing/VGI possibility. The focus was just in users for the reason that actually in Ethiopia the measurements are not done from landholder but from the expert of woreda office. Moreover, there are still some question marks related to VGI/crowdsourcing that need to be reviewed before implementing in poor countries where the registration process is sensitive in such changes that may result not very effective.

For example the study carried out from Keenja, De-Vries, & Bennett (2012) saw crowdsourcing as threat for public cadastral organizations. A miss co-evolvement of cadastral institutions with neo-cadastre may result in increase of land conflicts (de Vries et al., 2015).
Still there are challenges for approaching crowdsourcing or VGI such as : authenticity, validity of information, (McLaren, 2011); level of accuracy (Kalantari & Rajabifard, 2012), verification of correctness of information (Navratil & Frank, 2013).

In general the research include the whole information needed to understand user requirements, adapt, design and test the app for cadastral data collection and in the end the evaluation. What could be done different are the different methodologies used during the research. The users were identified better during workshop rather than from literature. The users in itself explains their role and difficulties. A desk study can be done in order to understand the institutions responsibilities before field work and to have an idea. A direct interaction with users makes the information more easy to be understood.

8. CONCLUSIONS AND RECOMANDATIONS

In this last chapter of the research are presented conclusions of the author related to the research and future recommendations. The organization of the chapter is done based on sub-objectives order so can be clear and can include all the necessary information to the reader.

8.1. Conclusions

The main objective of this research was to test and to evaluate a mobile app which was developed for data collection purposes but which was not tested before for land administration data collection. The app selected was Collector for ArcGIS, which was tested on the field with the purpose to analyze the functional requirements. Based on those requirements an evaluation is done by the users to understand how the users may react against those type of changes on the system. The perception of the users about the app, combined with the expectations meet by users, the system, and land experts requirements are elements which defined if this app was the proper mobile apps to be used in cadastral data collection.

Land administration needs a new methodology, not because collected data with paper is not possible, but because collecting data with paper-based has a lot of disadvantages and need a lot of time. Collecting data will total station/GPS is costly and time-consuming and actual process in Ethiopia is still facing problems as human power and speed of the process due to the high number of parcels.

Research sub-objective one

To identify the apps available for cadastral data collection and to assess them against criteria for pro-poor and fit for purpose land administration

Sub-objective one sought to find different apps designed for different data collection. A desk study in combination with literature review was done to identify those apps. A detailed analyzes were done to understand which of the apps can be used for cadastral data collection, assessed against pro-poor and fit-for-purpose criteria, have the majority of elements required from experts and system. The apps taken into consideration were searched on the internet, in different mobile platforms for mobile apps and most of them were installed to see how they work.

The elements a mobile app should have for pro-poor are: affordable, transparent, accessible, equitable, record all type of rights, record secondary rights, record complex rights, simple, quick, avoid costly fees, reflect the real situation on the ground, no high accurate boundaries, enclosed to public institutions.
The elements an app should have for fit-for-purpose are: flexible, inclusive, affordable, reliable, attainable, upgradeable, general boundaries rather than fixed boundaries, one fit does not fit all.
Each of the elements was described in details in Chapter 4.

The list of apps, in the beginning, started with 30. Reduced on this list were the apps which: could not collect all type of necessary features (point, line, polygon); the apps which could not be installed on different operating systems; the apps which cost more than 10 Euros per month. Finally, we had 7 apps which could be used for cadastral data collection. The apps were: Collector for ArcGIS, Locus Free Pro, MapIt-GPS Data Collector, MAST Application Suite, Open Tenure and SuperSurv.

Moreover, from this list the app selected was Collector for ArcGIS, which differently from other apps has some characteristics as customized attributes, different operating systems, no need for programming skills and Bluetooth connection with an external device as GNSS.

Research sub-objective two

To discover the user requirements and system requirements for cadastral data collection in Ethiopia

The research objective two sought to discover the user requirements and the system requirements.
The new method selected for cadastral data collection should satisfy the people that are using it and should adapt to the system of the country where it is used. The users in Ethiopia include all institutions and people who are involved in the registration process. For the users and their role refer to chapter 7, session 7.1.

The elements an app should have depended on the user or the person point of view. Each of users requires an app depending on the work they do. The majority of the land experts distinguish the capturing of the relation Person-right-property as the first essential element.

Results confirmed that other elements required were: collect of all type of tenures, customized app, collect data in online/offline mode, allowing extra maps, satellite images or orthophotos, high zoom level, automatic update, connection with database, attaching pictures/documents, adapt to all citizens, option for illiterate people (voice recording), different operating systems, multilingual app, no need for programming skills, allow extra device as GNSS, decimetre accuracy, adapt to legal requirements.

It was found that extra elements required for Ethiopia system are: not costly equipment, fast delivery of services/products, specific attributes for different regions, connect to their local database, local language for the attributes, digital signature or fingerprints.

Research sub-objective three

To adapt, develop, apply and assess a new cadastral collection process for the case of Bahir Dar Zuria

The research objective three was necessary to understand the steps for adaption, design and implementation of an mobile app into cadastral system.

There were identified 3 stages in the adaption phase: Download the app, Prepare the data, Create and Share Maps. In the developing a new cadastral data process were needed just 4 stages: Preparation steps, Plan data collection, Data collection, Data management. In the process of testing, was concluded that the number of processes and actors involved on the process of data capturing and data visualization are reduced compared to the current method.

The results reveal that a new cadastral collection process could avoid repeated work, printing materials and digitizing. Direct connection to the database allows the field surveyors to verify, to edit, change and update the information in real time.
The analyses of the spatial data reveal that there are not big differences on data between current method and a new method. This results disprove the idea that mobile technology can not implemented for accurate data collection.

Despite the fact that Collector for ArcGIS was selected as an advanced, and newly developed app for spatial data collection some technical and functional requirements need to be updated or revised in order to reduce costs and make the app more efficient for cadastral data collection.

Research sub-objective four

To analyze the user satisfaction regarding the mobile app and the process of data collection

This research objective sought to understand the user satisfaction about data collection. There is two type of users, the people who are involved in decision making for the method used and the people who are directly involved in second registration data collection process.

The users in Ethiopia and interviewed people found the idea of a mobile app very useful and promising tool for land administration. The field surveyors found the mobile app tools which will speed up the data collection on the field and make the work more simple avoiding the orthophotos, pencil and tape measurements. The cadastral system will be more effective, more simple and the process of data collection will be accelerated with mobile tools.

Regarding the method of data collection in Ethiopia, was simple and cost effective but still lacking in terms of time. However, the methods evolved with the advancement of the technology, and from first registration to the second registration should have been taken into consideration more developed methods for concluding second registration.

The elements of the app which need further improvement from users were: the zoom level, the possibility to have digital pen drawing (stylus pen) over the mobile app, the fingerprints or digital signature, voice recording and accuracy of the apps.

To conclude, in terms of time and use the majority of the users agreed that the mobile app reduces the time of the collection process by reducing work and because of simplicity of the app. Regarding some of them found the app more expensive with the argument that the cost will increase due to the fact there is a license needed and the GNSS has its cost. Most of them see it as a promising tool for the time and cost at the same time.

8.2. Recommendations

The area where the mobile app was tested was in a developing country where the process of registration is still going one. Implementation of this method should be practiced in developed countries for update purposes of cadastral systems. The developing countries focus on methods who have already been tested or adapted in developing countries in order to be sure those methods have been effective.

The second registration in Ethiopia is going slow due to the factors affecting collection process. There are procedures and requirements such as bureaucracy of presence of neighbors during registration of a parcel which may be excluded since there is a community member present during registration. The requirement of fingerprint for farmers that cannot read, to approve information which they do not understand can be should be found a solution.

The restrictions on the land rights, such as the right of land use just for 2 years, should be reconsidered. This is a restriction that is not applied and if in the future will be applied the second registration will be invaluable.

Regarding the implementation of mobile apps into cadastral systems better advertising should be done to inform users worldwide and institutions for the possibilities they have implementing those low-cost methods.
Further studies can be done about:

- Willing of the governments to accept and to adapt mobile technologies in a cadastral system.
- Implementation of the mobile apps directly for cadastral data collection should have further studies in the way how the collected information can be check in order to avoid corruption.
- Analysis of the farmers and landholder belief about capturing the data with a mobile app should be taken into consideration.
- Future studies should be carried out for the implementation of ArcGIS on government institutions and their cost

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APPENDIX 1

Questionnaires Field Experts

1. Did you try to measure/ collect data with the app? YES/ NO

2.How do you find the app tested on the field?

3. How will you evaluate the performance of app?

POOR GOOD VERY GOOD EXCELLENT

4.If you had the right to choose method of data collection would you prefer the app or the paper based form?

YES/ NO

Why?____

5. Do you find it faster in comparison with the method you are using now? YES / NO

6. How many parcel do you collect per day with paper form?

7.How many parcel did you measure with the mobile app?

EXPLAIN____

8. Did you find the process of data collection difficult?

YES/NO____

9.Could you collect and visualize all necessary data?

YES/ NO
EXPLAIN____

10.What did you like and what you didn't like from using this app? (list elements)

\+ -
\+ -
11.What can be improved on the app from your opinion?
____

Questionnaires Land Experts

Name **Surname** **Work Position**

1. What is your opinion for implementing a mobile app for cadastral data collection?

2.How to you find the actual methods used for cadastral data collection?

3.Do you think that with current speed the registration process in Amhara region will be completed in time?

4. Do you find the new methodology faster in comparison with actual methodology?

5. Do you think implementing this methodology reduce costs of land registration processes?

6. Do you find it cheaper or more expensive compared to actual methods?

Cheaper More Expensive Unknown

7.What did you like and what you didn't like from this app? (list elements)

+ -

8. What can be improved to the actual app from your perspective?

Interview Themes	Workshop Themes
Ethiopia professionals -Second Registration -Institutions involved -Role of the users -Process of work in 2-nd registration -Methodology used -Cost and time -Opinion about mobile app for LA - Requirements they find important Land professionals Apps for land administration Requirements that should have an app for land administration Challenges and restrictions Personal experience with mobile app or cadastral data collection processes	- Role of experts - Steps for actual data collection - Steps for data entering and certificate production -Steps should be followed for fieldwork data collection -Steps for implementing app into cadastral system -Difficulties they face during their work **Group Discussion** - Fieldwork data collection - Comparison of methodologies - Advantages / disadvantages -Opinion about the mobile app implementation

APPENDIX 2

Pro-poor and fit-for-purpose criteria's

	Criteria	Description	Source
Pro-poor	Affordable (Avoid costly fees)/ Transparent/ Accessible/ Equitable	Be inexpensive, low-cost tools to be affordable from government and citizens. Cheap equipments (low-cost) and methods Give the landholder the possibility to understand the systems and tools. clear cost, services, methods and procedures. Access to information and services without the need of professional knowledge's. Method of data collection that records all citizen without any differentiation despite religious, age, ethnicity. (woman's rights)	(Zevenbergen et al., 2012)
	Include Complex rights, formal tenures, customary and informal tenures and secondary rights	Method which adapt a method that offers customized attributes based on the country in order to allow complex right recordation and secondary rights. Formal and informal (Continuum of rights)	
	Build based on social tenure (Simple/ Quick)	Easy and simple method to be understood from landholders and easy to be used from professional avoiding complex systems No time consuming processes for collection, visualization and data analysis	
	Close to the people	A collaboration with the people, will improve land management and planning.	
	Geometrical index	In order to represent what is on the ground directly on the mao a geometrical index is needed for cadastral systems.	
	No high accurate boundaries and complete data 91st stage)	No accurate boundaries in areas where is not necessary. A method of not-high precision (decimeter) is acceptable. Mostly for the areas where the registration is done for the first time the general boundaries and basic data are useful .	
	Land record management as part of public administration.	Pro-poor land records office enclosed to public institutions. Method should capture data that can be used for different institutions, support collaboration, data exchange and link of data between different institutions. This will avoid the manipulations on the system and moreover effectiveness on the services.	
	Co-management of pro-poor land record	Include the present of witnesses, to create evidences, legitimacy of land records. Protection of the people rights.	
	Deliver justice	The system should be fair and understood from everyone. To make clear for the landholders their rights, limits, restriction and the information can be accessible and free for everyone	

Fit-for-purpose	Affordable	A method that can be adapted easily for the institutions involved, used easily in the terrain where the land registration will be carried on and despite technical and financial conditions (low-cost), affordable even for the social conditions.	(Enemark et al., 2014)
	Flexible	be elastic to make the possible inclusion of all user types and systems for capturing different data for different purposes, allowing participatory mapping, extra maps.	
	Inclusive	A single tool that allows the registration of all type of information, all type of tenure	
	Reliable	The methods should collect reliable information. The users and landholder should trust on methodology and information collected. This can be achieved with understanding of it	
	Participatory	Participatory method that is supported from citizens in capturing the data	
	Attainable	Method used should be obtainable from the country and people who will implement it. Adapt fast, includes devices and systems which are available rapidly, learned easily from the users and countries	
	Upgradeable	A method that can adapt to changes on every aspect as legal, technical, economical and social.	

Main Papers reviewed in order to understand the meaning of the criteria's and its implementation. Based on combination of papers there was made possible the above mentioned descriptions

Pro-poor

Source	**Main Idea**
Social Tenure Domain Model: Requirements from the Perspective of Pro-Poor Land Management (Augustinus, Lemmen, & Oosterom, 2006)	The paper makes a analysis of the first requirements STDM should have for a better land administration tool based on pro-poor and requirements to include on CCDM (Core Cadastral Domain Model)
The Social Tenure Domain Model (Lemmen, 2010)	This report gives information about model of pro-poor land administration system (STDM). It a report analyze the benefits of using a pro-poor tool in developing countries.
Designing a land records system for the poor (Zevenbergen et al., 2012)	This publication presents a broader idea about benefits of land recorder and emphasizes the problems of the poor people and why they need new land record systems.
Handling Land Tools for land governance and secure tenure (GLTN, 2012)	This book gives us the understanding about different land tools and policies that GLTN try to implement. It explains the work of GLTN by developing institutions and providing them with pro-poor land tools for promoting sustainable development.

Pro-poor land administration: Principles for recording the land rights of the underrepresented (Zevenbergen et al., 2013)	This article discusses new innovative pro-poor reforms and the new form of tenure security enabled by implementing those reforms. This is based on the finding of the authors and previous studies about the elements and principles for design conventional land administration systems based on the concept of pro-poor.
Systems approach to pro-poor land reforms: A concept paper (Anaafo, 2013)	The paper is relevant because it makes the link between land reform based on pro-poor concepts and analyzes the way how to improve and sustain those approaches.

Fit-for-purpose

Source	**Main Idea**
The Land Administration Domain Model (Lemmen, van Oosterom, & Bennett, 2015)	This paper is based on a description of LADM, a standard of land administration. The LADM supports the implementation of fit-for-purpose and explains why this is relevant for land systems.
Fit-For-Purpose Land Administration (Enemark et al., 2014)	This book explains the need of building cost-effective and sustainable systems with the approach of "fit-for-purpose". It provides a deep explanation about the concept of "fit-for-purpose" and basic components of this concept.
Fit-for-purpose land administrations: lessons from urban and rural Ethiopia (R. M. Bennett & Alemie, 2015)	The article describes the effect of fit-for-purpose land administration on reducing poverty, providing food security and good governance in developing countries as Ethiopia.
FIT-FOR-PURPOSE LAND ADMINISTRATION in Support of the Post 2015 Global Agenda (Enemark, 2015)	The paper present an understanding of land administration and indicates that fit-for-purpose approach should be flexible and should be focused on giving the services and results for the developing countries that need a fast improvement, this in support of Post 2015 Global Agenda.

APPENDIX 3

3D GIS - or 3D-GIS in the Cloud was developed years ago for capturing data for: city planning, infrastructures, roads and cadastre management. It is designed for capturing 2d and 3d views. It specifies that is for iPad or Smartphone but couldn't find it on play store. After reading abut he app that mostly can collect a huge information that can be used for 3D cadastre in developed countries. For using its needed a license. It allows different type of formats for data collection and in the same time the connection with databases. Was excluded from the list because it is more advance for collecting 3d data rather than points, line and polygons for cadastral purpose.
Information retrieved from : http://www.sivandesign.com/products/3dgis

ArcGIS - was designed to support collection in the field, office data , community and builders. The focus of the app was : to share maps, crowd sourcing and data editing. The function of the app are similar as Collector but unfortunately this will be used just from people who had access before of 2016 do download the app. After will be impossible to find the app for download. Main reason why was eliminated from the list.. To have access to the app you need to pay(unknown amount).
Information retrieved from: http://www.esri.com/software/arcgis/arcgis-app-for-smartphones-and-tablets
http://www.arcgis.com/features/apps/
http://doc.arcgis.com/en/arcgis-app/

ArcPAD ESRI -

The app was developed from ESRI for being used for GIS professionals in order to collect data with a mobile in this way they could save time and manage assets. The app offer the possibility to: collect, edit, display the geographic information efficiently and quickly. It allows multi-users and access on personal geo-database and allows sharing between your organization. The main things that make the ArcPAD special are data synchronization, the possibility to integrate with ArcGIS online, and automated field data collection.
The pricing for the app is not on the webpage. In case you want to use it you need to contact your local ESRI office. Its needed an external device. Can't be found on Android Play store and was not tried before the selection of the app.
Information retrieved from : http://www.esri.com/software/arcgis/arcpad
http://www.esri.com/~/media/Files/Pdfs/industries/locationservices/pdfs/arcpad-field-users-guide.pdf

CyberTracer - Designed for environmental monitoring and has been used from a long time in different fields as: scientific research , environmental, health surveying, disaster relief and other more . No previous studies for land administration. Doesn't require programming skills and allows you to customize an app. Was originally designed for trackers who cannot read and write. Now is developed for all type of users. I gives you the possibility with icon to collect data. Gives the possibility to see the data in graphs, in maps or in tables. Different files as xml,html, esri shape files. You can record the path you are doing. Is not possible to be downloaded on Android. Couldn't try it before fieldwork. You need to have windows device. Eliminated because the windows phone was difficult to be found since mostly we have android or iOS.
Information retrieved from : http://www.cybertracker.org/software/getting-started

DataPoint - Is an app developed for data collection, mostly vegetation as plot, line, point or density . The file that you can use are CSV for export and import. The cost of the app for user is 110,94 euro. The geographic information is capture via GPS or using an external GPS. This app except it cost per user, is not proper for cadastral data collection since it focus more on data type just vegetation. Is not customized app that can be included as fit-for-purpose. No need for cloud computing or network connectivity. The trial is just for 5 days

in case you want to use and the attributes look a bit complicated for an app that can be adapted to collect cadastral data. Reason of being eliminated are: price and not flexible app for other type of data collection
Information retrieved from: https://play.google.com/store/apps/details?id=com.esp.DataPoint&hl=en

Field Tracer - Was developed from Dirt Tech. It can offer the possibility to be used in: surveying, navigation, RTX data, and soil mapping which is the main focus. Feature that you can collect are: point, line, polygon, area, distance. Different formats as : SHP, JPEG, PNG. You can't connect to a database but to organize your data you need an drop box account. It allows external device such as GPS. Is just for Android app and the cost is 200$ for year. Doesn't allow to have customized attributes. Looks simple for data collection but not sure if this can be used for data collection as cadastral data when you need it for national use ,maybe good for local data collection.
Information retrieved from: https://play.google.com/store/apps/details?id=com.dirttech.fieldtracer
https://www.dirttech.com/node/1754

Fulcrum -
Is special for capturing signatures something other apps has lack for capturing this information. Is in different languages.. It gives the possibility to capture pictures and videos with geographic information attached, text, barcodes, GPS location, spatial audio and more. Is support offline data collection and mapping for environmental observation, field audits, and inspections. Different type of data formats. You can connect data later on with other services as GIS. This app was used from CartoDb for data collection. Reason why was refused was because it doesn't give the possibility to use it for capturing land information data in deep as other app that can be developed for that purpose.
Information retrieved from:
https://itunes.apple.com/us/app/fulcrum/id467758260?mt=8
https://play.google.com/store/apps/details?id=com.spatialnetworks.fulcrum&hl=en
http://docs.cartodb.com/tutorials/data_collection_fulcrum/
http://www.fulcrumapp.com/

Geo-Wiki -
The app was designed for citizen engaging in data collection in environmental monitoring. The reason of the app was to collect data in order to validate global land cover maps derived from satellite. The citizen can collect data via photos which are automatically geo-referenced and with the picture you can tag the information collected on the field. Can be used in case of land use but not completely cadastral data collection. This is reason why was eliminated.
Information retrieved from: http://www.geo-wiki.org/mobile-apps/
https://play.google.com/store/apps/details?id=GeoWikiMobile.GeoWikiMobile&hl=en

GIS Kit & GIS Pro -
The GIS pro and GIS kit are very similar apps which were designed to support: map performance, drawing tools, working offline, customs features, multiple projects, import export possibilities.
They have some differences as: Po allows you to have import of maps as: SHP and CSV with attributes. It gives the feature in WMS and raster and allows you to share data. Both of the apps can be used for collection of accurate and sophisticated data from individuals or professionals. Both of the apps are in payment and they are available only for IOS users reason why was refused.
Information retrieved from:

http://gis.garafa.com/GISPro_%26_GIS_Kit/GIS_Pro_%26_GIS_Kit_for_iPhone_%26_iPad.html
https://itunes.apple.com/us/app/gis-kit/id429688355?mt=8

GISRoam -
Is a free app which allows data collection over maps and satellites. It allows the collection of all type of features as line, polygon, point with or without GPS. It give the possibility of working offline and in new or existing shape files. GISRoam was designed to be used from professionals in data collection or field observation. Compared to other apps this offers to the user to capture data related to the elevation. The reason why was refused is that cannot be used from people who has a cheap phone as windows or android.
Information retrieved from:
http://appcrawlr.com/ios/gisroam
http://mundogeo.com/en/blog/2010/11/25/gisroam-v2-1-ipadiphone-alternative-to-arcpad/

GPSEssentials -
allows the collection of lines and polygons by tracing your route. It can be used for going around the parcels and collecting that route but is not what is required for the purpose of this research. The app is god for navigation purpose and can give you information about distance, altitude, latitude and longitude and many more but is difficult to be sued for collection of cadastral data which need specific attributes which should be customized.
Reason of rejection was that cannot collect land tenure attributes.
Information retrieved from:
https://play.google.com/store/apps/details?id=com.mictale.gpsessentials
http://downloads.tomsguide.com/GPS-Essentials,0301-49666.html

IGIS -
Was designed for users that want to load, view, collect, create and export data. It supports multi features as lines, points, polygons and to have different base maps. It has GPS location, map pan, zoom in and out, support large datasets. Is designed for GIS professionals and requires some GIS skills. Reason why was refused were the fact that the app can be used just from users who has IOS operating system.
Information retrieved from:
https://itunes.apple.com/us/app/igis/id338967404?mt=8
http://www.geometryit.com/igis/

Integrity GIS -
Is an app which was designed to be used from users everywhere in the world for collection and editing GIS data. App has the possibility to measure length, area or units. Take pictures, has map layers and allows map legend. The reason why was excluded was because is needed an app which allows collection of lines, point, polygon, to retrieve coordinates and collect the relation person-right-property.
Information retrieved from:
http://www.midlandgis.com/2012/10/08/integrity-mobile-gis-iphone-ipad/
http://geodatapoint.com/articles/print/integrity_mobile_gis_now_available_on_iphone_and_ipad

MapGo GIS Data Collection -
Is a mobile app designed for data collection. The app allows, multiple layers management, easy record on the field. Clear recognition because of the used base maps. Useful map tools as GPS for measuring, zoom in the field over you map, selection of the feature and seeing attributes, area measurements , layers, measure point, line , distance, extent. The app is easy to use and you can download the KML file after data collection. The app gives information about latitude and longitude plus geo-coding. The app has even the service of the cloud, which is free but the app in itself is with payment.
Information retrieved from:
http://www.mapgogis.com/
https://itunes.apple.com/us/app/mapgo-gis-data-collection/id654912231?mt=8
http://www.mapgogis.com/

Mobile Data Collection -
The app was designed just for data collection. Can be download in android and iOS operating system. It has a real time GPS location service which allows to collect data in real time. The precision of the app depend on the mobile or table t you are using. It offers offline data collection and you can explore maps and projects directly from the field. The app supports could based maps, allows custom forms designers, data editing , spatial queries and analysis. Cost is 20$ user/month
To capture videos and capture of the voice.
Information retrieved from:
http://www.giscloud.com/apps/mobile-data-collection
https://itunes.apple.com/us/app/gis-cloud-mobile-data-collection/id640535923?mt=8
https://play.google.com/store/apps/details?id=com.giscloud.mdc&hl=en

Mobile GIS or GIS2GO -
Is designed to allow ESRI maps to be download on the device and use them offline. The app has a lot of functionalities, as selection, export, import via the cloud. The app allows to get notes, to take photos and import everything you have create on ArcGIS Desktop. The app can be installed in android and iOS operating system. The app allows the capturing of the points, line and polygons the reason why the app was removed is because of it cost. 1 mobile device with 5GB hosting space cost 390 euro each year.
Information retrieved from :
http://www.gis2go.com/home-en.html
https://play.google.com/store/apps/details?id=net.disy.gisterm.mobile.android.dev&hl=en

My maps -
The pro version of the app that can be installed in ios and android operating systems that allows you to collect data , lines and polygons. To use the Google maps and cache map for offline use. The app is not designed for being used for the purpose of land data capturing but mostly to capture data in the place where you visit. So you can have a track of the places and geographic information where you were.
Information retrieved from:
https://itunes.apple.com/us/app/my-maps/id620245309?mt=8
https://play.google.com/store/apps/details?id=com.google.android.apps.m4b&hl=en

Pocket Earth -
Is an app that allows you to have all the maps of the world in your mobile and this you can use them for any purpose. It allows to have GPS Track . You can even record points with their geographic information. The app is designed for navigation purpose rather than for collection. Despite the fact that you can collect information is not the first purpose. Reason why was excluded.
Information retrieved from:
https://pocketearth.com/
https://itunes.apple.com/us/app/pocket-earth-pro-offline-maps/id481679745?mt=8

Point GIS -

Is a offline mobile data collector which works offline. The app allows the user to transfer the data collected from the mobile phone to a collector gadget. It is free, give the local data storage and data can be edit. The app is good to be sued because it give the coordinates in the real time and it give the accuracy. The app cannot collect land tenure types and moreover cannot collect polygons or lines. This was the reason why was excluded.

Information retrieved from:

https://play.google.com/store/apps/details?id=com.gis.pointgis

https://www.androidpit.com/app/com.gis.pointgis

SuperSurv M3--GPS Plug-in -

Is designed for data collection for surveying purposes. The app give the possibility to retrieve advance positioning settings. To connect with external device for improving the accuracy. Retrieve X,Y coordinates, all types of features, point, line, polygon. Offline data capturing of SHP/GEO. Global users but local coordinates. The main functions of SuperSurv M3 include data collection, orientation, and map display. With the built-in GPS functions, the data of point, line and polygon can all be captured quickly. Users can apply OpenStreetMap as base map to collect spatial data. Was excluded because of the cost. Cost 53,43 euro

Information retrieved from:

https://play.google.com/store/apps/details?id=supersurv.gpsplugin

http://apk-dl.com/supersurv-m3-gps-plug-in

https://www.mobileaction.co/app/android/us/supersurv-m3-gps-plug-in/supersurv.gpsplugin

View Ranger -

The app is for free and can be download in every device and can be used offline. Can track the position where you are located with coordinates and can even track the route you are doing, taking pictures and later on you can transfer you data directly on your pc. The first purpose of the app is navigation rather than collection so the app is excluded because it doesn't offer the possibility to be used for professional purpose as data collection in land administration.

Information retrieved from:

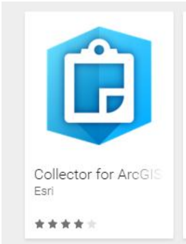
https://play.google.com/store/apps/details?id=com.augmentra.viewranger.android&hl=en

http://www.viewranger.com/en-gb

Wolf-GIS -

Is designed for data collection and for collecting geographic information as for property boundaries, for awareness and critical factor. Wolf-GIS is useful to those working in timber management, mining, real estate, utility companies, farming, construction, government land agencies, recreational purposes and more. You can collect latitude, longitude, display GPS, take picture, measure, import, export shape files , navigate, Reason

STEPS FOR USING COLLECTOR



1. DOWNLOAD APP

Check the version of your android. Is required an Android of version 4.0 and up .
Make sure you have the right space on your mobile (Actually 24MB)
On play store on search for "collector" and from the list select the app "Collector for ArcGIS" ESRI.
Install the app on your phone and you can select to use the trail or use your ArcGIS online account.
After installation your app will have no maps and no feature attributes. To make maps for data collection were followed the tutorial of ESRI online http://doc.arcgis.com/en/collector/#features

2. PREPARE YOUR DATA in ArcGIS for desktop
http://doc.arcgis.com/en/collector/windows/create-maps/prepare-data-desktop.htm

3. CREATE AND SHARE A MAP for data collection
http://doc.arcgis.com/en/collector/windows/create-maps/create-and-share-a-collector-map.htm

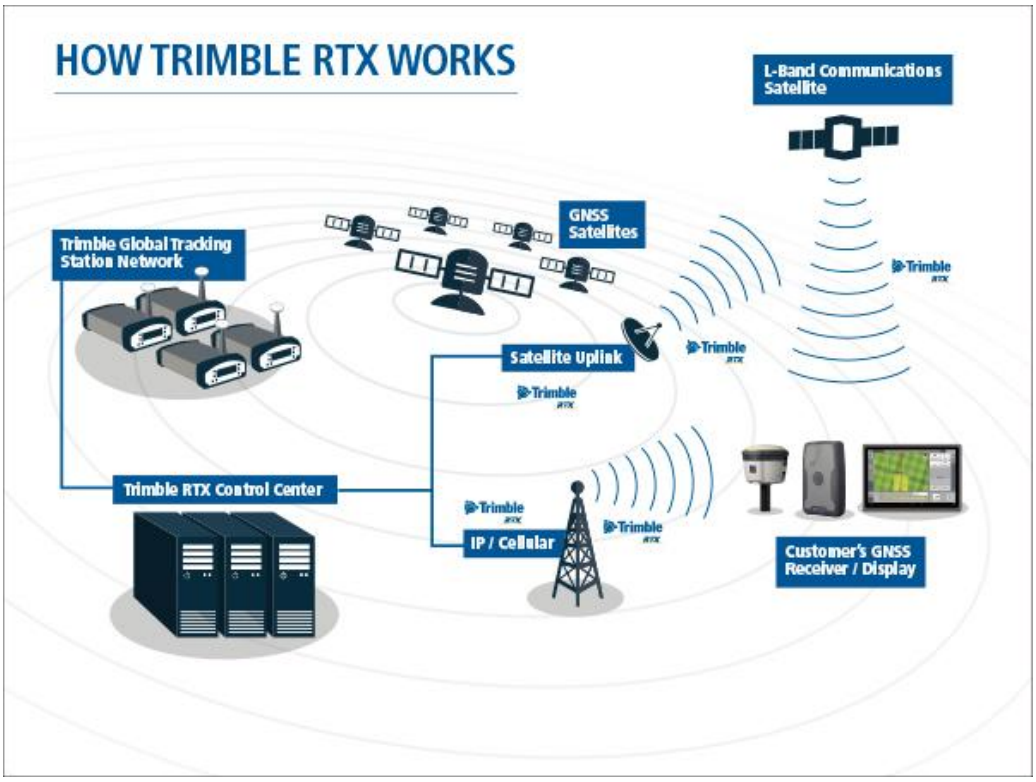
4. COLLECT DATA ONLINE
http://doc.arcgis.com/en/collector/windows/collect-data/collect-tutorial.htm

5. PREPARE AND COLLECT DATA OFFLINE
http://doc.arcgis.com/en/collector/windows/collect-data/offline-use.htm

APPENDIX 5

TRIMBLE GNSS (Trimble, 2015)

RTX Correction Signal (Trimble, 2015)



APPENDIX 6

Field registration form for cadastral mapping in Wojir, Bahir Dar Zuria

General information

Team no. _______ Field map no. ________________

Holding/Parcel ID ______________ Survey date (Ethiopian, Y/M/D)___________________________

Holding type

☐ Not known	☐ Group	Comment
☐ Governmental	☐ Private	
☐ Communal	☐ Other	

Holding evidence

☐ No evidence shown	☐ Book of holding	Comment
☐ Tax receipt shown	Book of holding number	
☐ Court decision shown		

ISLA confirmation

OK Change

☐ ☐ Land holder(s) ______________________________ ______________________________

______________________________ ______________________________

______________________________ ______________________________

☐ ☐ Guardian ____

☐ ☐ Subkebele/Got ______________________________ Area ______________________

☐ ☐ Land use

☐ Not known	☐ Homestead, garden	☐ Bare land
☐ Perennial crop	☐ Forest	☐ Other
☐ Annual crop	☐ Grazing land	
Comment		

☐ ☐ Fertility

☐ Not known	☐ Medium	Comment
☐ High	☐ Low	

☐ ☐ Neighbour East ________________________ West ____________________________

North ________________________ South____________________________

Additional information

Guardian address ____

Encumbrances

☐ No encumbrance	☐ Footpath	☐ Water pipeline
☐ Not known	☐ Electricity line	☐ Waterway/flooding outlet
☐ Asphalt road	☐ Telephone line	☐ Irrigation canal
☐ Gravel road	Comment	
☐ Other		

Disputes

☐ No dispute	☐ Holdership dispute	Comment
☐ Not known	☐ Boundary dispute	

Other information ____

Signatures

Land holder ______________________________________

LAC member ____________________________ Team leader_____________________________

APPENDIX 7

Attributes needed for cadastral data collection

Id	Name	Type	Type name	Length	Precision	Comment	Edit widget	Alias	WMS	WFS
0	Name	QString	String	254	0		Text Edit		X	X
1	TeamNo	int	Integer	1	0		Text Edit	Team number	X	X
2	FieldMapNo	int	Integer	3	0		Text Edit	Field map number	X	X
3	RegionID	int	Integer	2	0		Text Edit	Region ID	X	X
4	ZoneID	int	Integer	2	0		Text Edit	Zone ID	X	X
5	WoredaID	int	Integer	2	0		Text Edit	Woreda ID	X	X
6	KebeleID	int	Integer	3	0		Text Edit	Kebele ID	X	X
7	HoldParcel	QString	String	19	0		Text Edit	Holding/Parcel ID	X	X
8	SurveyDate	QString	String	10	0		Text Edit	Survey date (EC)	X	X
9	HoldingTyp	QString	String	50	0		Text Edit	Holding type	X	X
10	Evidence	QString	String	50	0		Text Edit	Evidence type	X	X
11	RegBookNo	int	Integer	10	0		Text Edit	Registration book number	X	X
12	RegChange	QString	String	24	0		Text Edit	Change in existing registry	X	X
13	LandHold1	QString	String	50	0		Text Edit	Land holder (first)	X	X
14	LandHold2	QString	String	50	0		Text Edit	Land holder (second)	X	X
15	LandUse	QString	String	22	0		Text Edit	Land use	X	X
16	Fertility	QString	String	20	0		Text Edit	Land fertility	X	X
17	GuardAdr	QString	String	100	0		Text Edit	Guardian address	X	X
18	Encumbranc	QString	String	60	0		Text Edit	Encumbrances	X	X
19	Dispute	QString	String	50	0		Text Edit	Dispute type	X	X
20	AddInfo	QString	String	238	0		Text Edit	Additional information	X	X
21	Signatures	QString	String	21	0		Text Edit	Signatures complete	X	X
22	Area(ha)	double	Real	8	4		Text Edit	Area (ha)	X	X

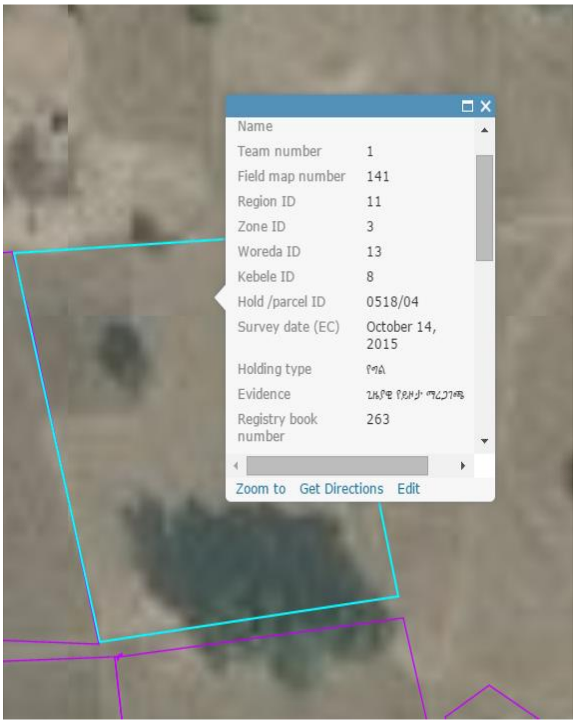
Relations

Suppress attribute form pop-up after feature creation Default

Load Style ... | Save As Default | Restore Default Style | Save Style

OK | Cancel | Apply | Help

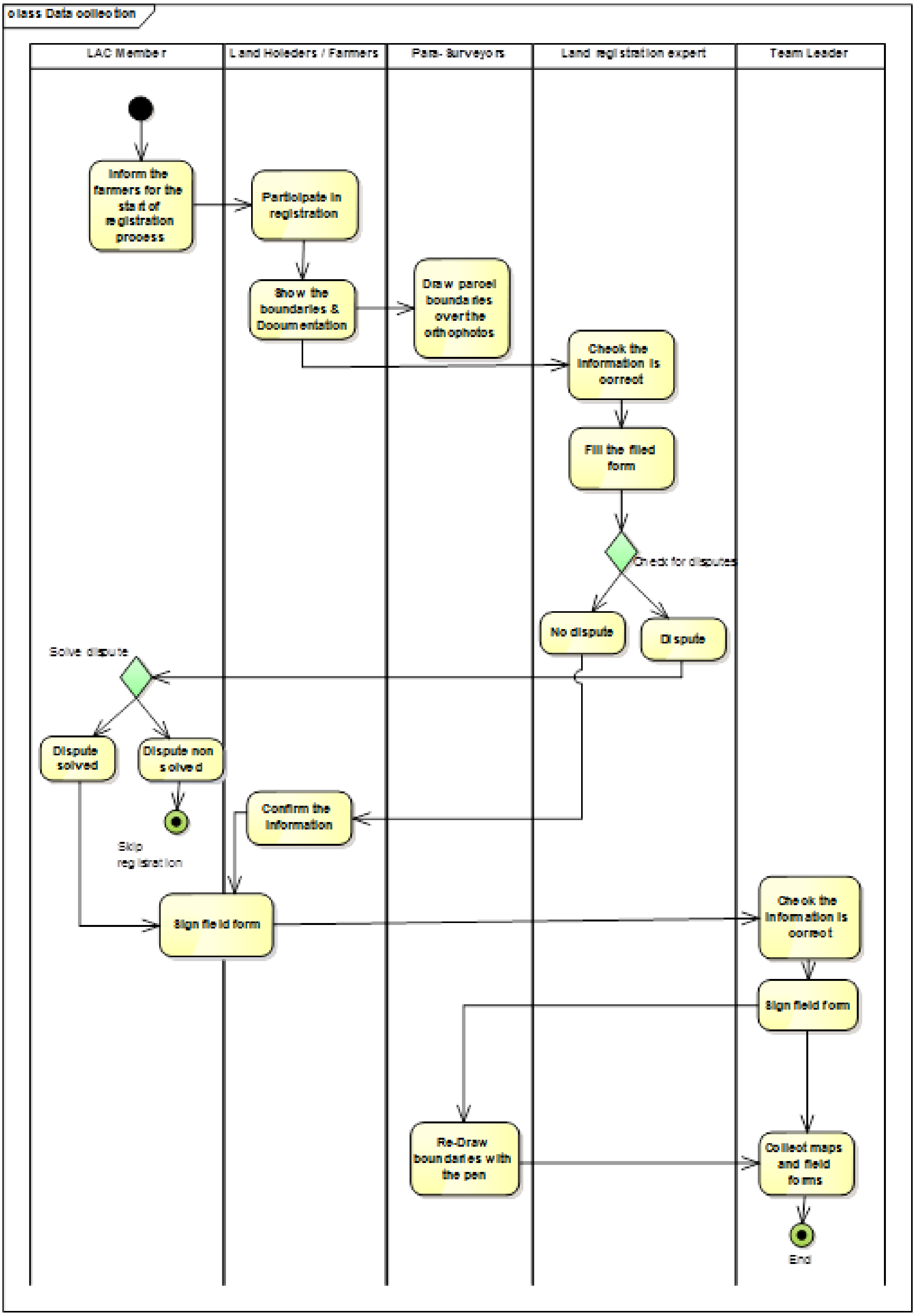
TeamNo	1
FieldMapNo	141
RegionID	0
ZoneID	0
WoredaID	0
KebeleID	0
HoldParcel	0477/04
SurveyDate	10/14/2015
HoldingTyp	የግል
Evidence	የይዞታ ማረጋገጫ ደብተር
RegBookNo	26385
RegChange	2638563
LandHold1	
LandHold2	
LandUse	አመታዊ ሰብል
Fertility	ከፍተኛ
GuardAdr	
Encumbranc	የለም
Dispute	የለም
AddInfo	
Signatures	Yes
Area_ha	0.84
CentroidE	0
CentroidN	0
Rownumber	0
EditNotes	
Computer	0



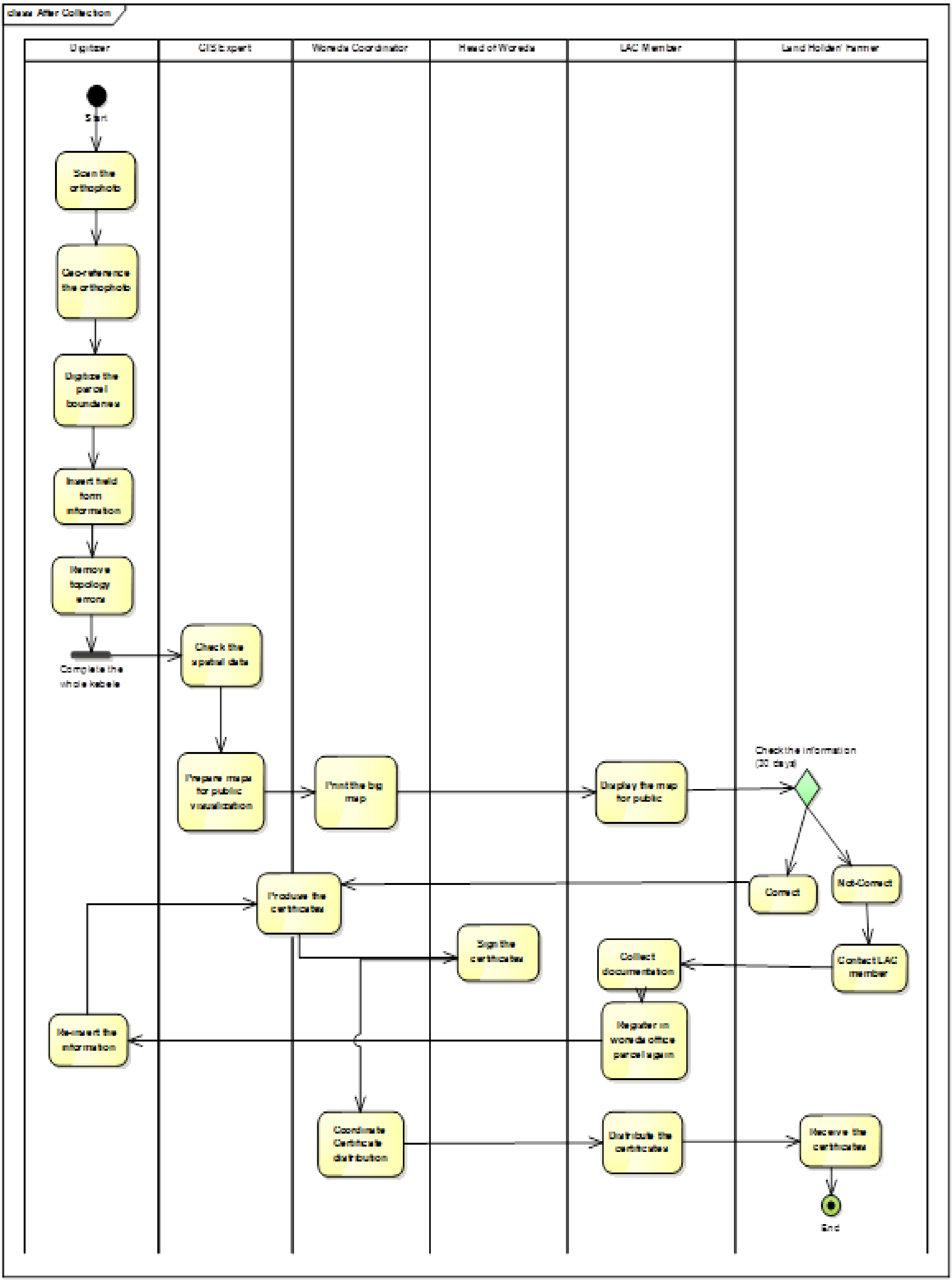
Attributes collected with Collector for ArcGIS

APPENDIX 8

UML Activity Diagram for data collection

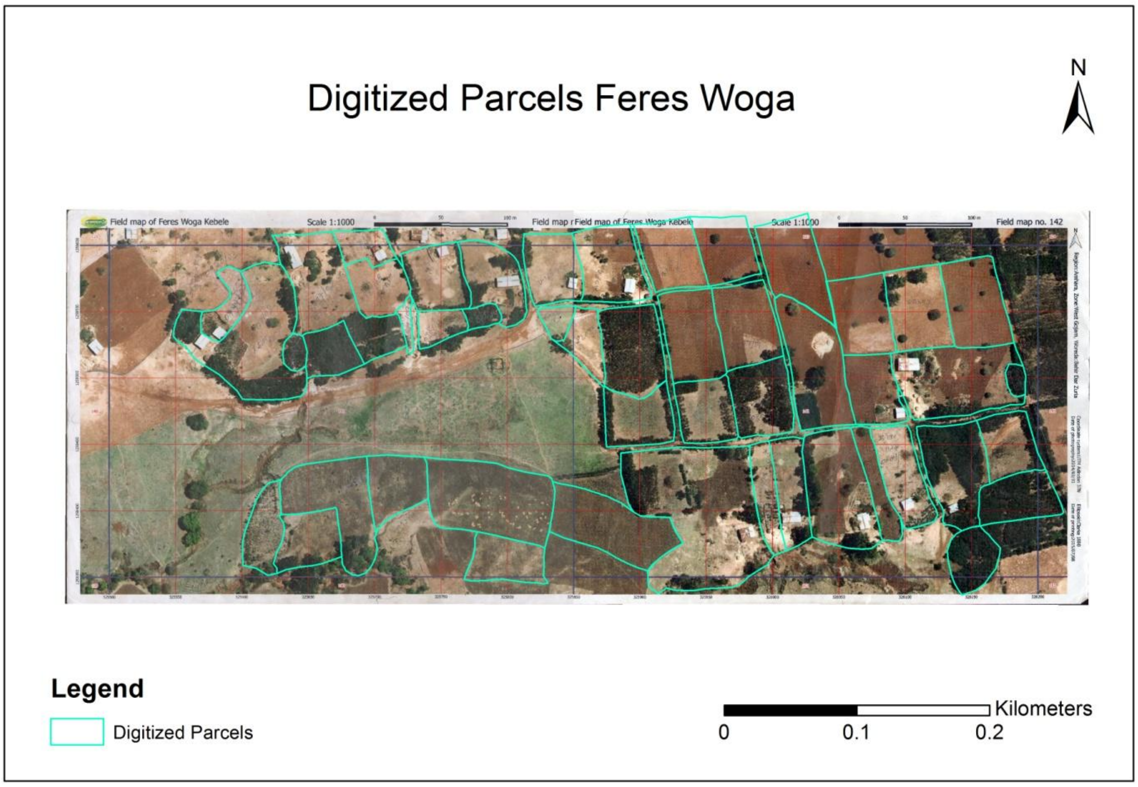


UML Activity Diagram for processes after data collection

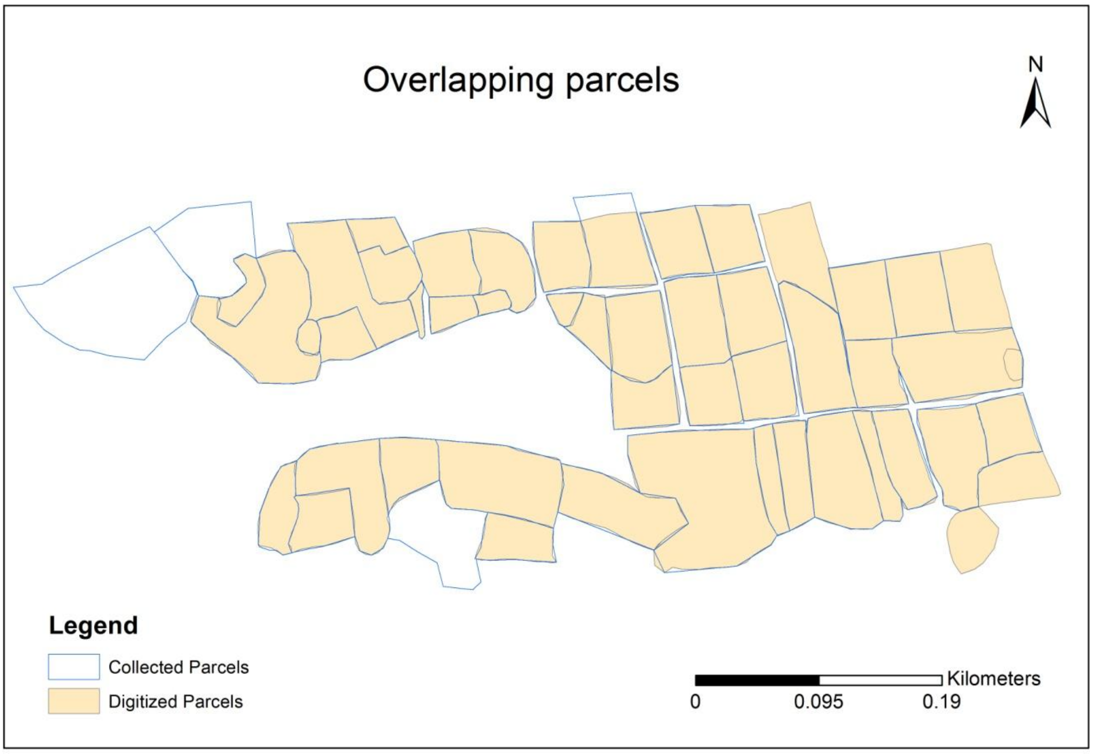


APPENDIX 9

Map of digitized parcels over the orthophoto (Own creation)



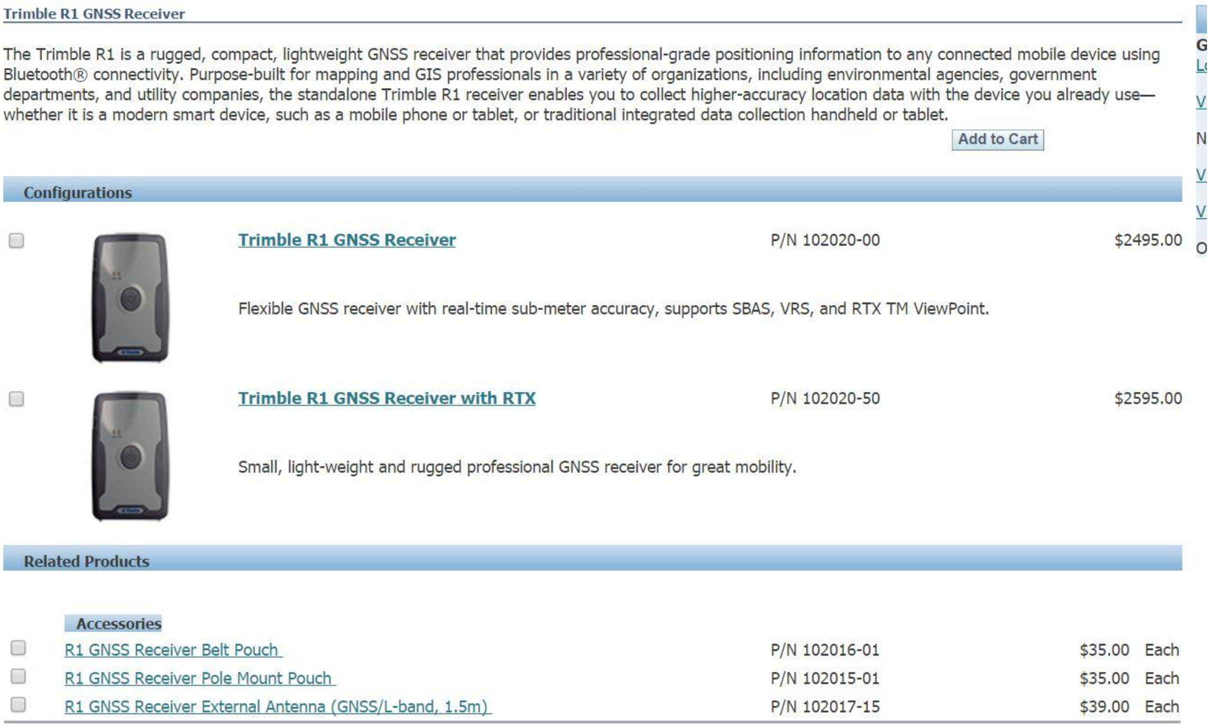
Map showing overlap between collected data and digitized data



APPENDIX 10

Cost for the GNSS

1 GNSS cost from 2495$ - 2753 $. (Information retrieved from:
https://store.trimble.com/OA_HTML/ibeCCtpSctDspRte.jsp?section=96797&sitex=10140:22372:US)
from Let's suppose an equipment can be used for 5 years
2753 X 5 = 13765 $ price for 5 years.
In one year there are around 200 working days excluding weekends and holidays.
So we can say that the GNSS will be used 1000 days.
For day the cost of using the GNSS will be : 13765/100 = 13.765 $
Per day one field surveyor can collect around 50 parcels.
With the use of GNSS the cst per parcel will be: 13.765/50= 0.28 $
Actually in Ethiopia are in total 50 000 000 parcels
for registering 50 000 000 parcels are needed 1000 GNSS
1 GNSS - 50 PARCELS/DAY
1GNSS - 200DAY X 50 PARCEL/DAY = 10 000 PARCELS PER YEAR.
1GNSS - 10 000 PARCELS/ YEAR X 5 YEARS = 50 000 PARCELS
For 50 000 000 parcels: (50 000 000 parcels in total)/(50 000 parcels/year)= 1000 GNSS needed.
So if Ethiopia government needs to have high accurate boundaries, and to speed up the registration process they need an investment minimum for 1000 GNSS in order to cover the registration process for 5 years.



Trimble R1 GNSS Receiver

The Trimble R1 is a rugged, compact, lightweight GNSS receiver that provides professional-grade positioning information to any connected mobile device using Bluetooth® connectivity. Purpose-built for mapping and GIS professionals in a variety of organizations, including environmental agencies, government departments, and utility companies, the standalone Trimble R1 receiver enables you to collect higher-accuracy location data with the device you already use—whether it is a modern smart device, such as a mobile phone or tablet, or traditional integrated data collection handheld or tablet.

Add to Cart

Configurations

Trimble R1 GNSS Receiver Flexible GNSS receiver with real-time sub-meter accuracy, supports SBAS, VRS, and RTX TM ViewPoint.	P/N 102020-00	$2495.00	
Trimble R1 GNSS Receiver with RTX Small, light-weight and rugged professional GNSS receiver for great mobility.	P/N 102020-50	$2595.00	

Related Products

Accessories

R1 GNSS Receiver Belt Pouch	P/N 102016-01	$35.00	Each
R1 GNSS Receiver Pole Mount Pouch	P/N 102015-01	$35.00	Each
R1 GNSS Receiver External Antenna (GNSS/L-band, 1.5m)	P/N 102017-15	$39.00	Each

Cost for ESRI account

Cost for orthophoto

1 square km - 600 birr around 28 $
1 104 300 km whole area of Ethiopia
Price for the whole Ethiopia for Orthophoto is :
28 x 1 104300 = 30 920400 $
Price for Amhara region for orthophoto is :
28 x 154 709 = 4331852 $
In Amhara region there are in total 49,676,000 (50 000 000)
Price per parcel for orthophoto will be : 43 31852 / 50 000 000 = 0.08 $

Cost for orthophoto printing

From fieldwork was collected the information that for 3 kebeles the ink for printing the orthophotos was 40 000 birr, around 1878 $.
Per kebele is around 626 $ printing of orthophoto.
In Amhara there are 108 kebeles
So 108 x 600 $ minimum = 64 800 $ just printing cost
Cost per parcel for printing are:
64 800 $ / 50 000 000 parcels = 0.001 $

Cost for digitizing.

4 digitizer should digitize per day 40 parcels. Minimum. So they can digitize per day 160 parcels each day. In case will be avoid the data entering and the digitizing, the time needed for one parcel will be less. So the digitizer will check just for topology errors and it can make double of parcels he is doing now, not 40 but 80, or minimum with this method can make 60 per day. Another cost reduce will be for the time needed from the digitizers.

Employees salaries

Type of job	**Number**	**Salary**	**Profession**
Digitizers	4	4000.00 ET Birr	Diploma (10+3)
Surveyors	4	3500.00 ET Birr	Diploma (10+3)
Land registration experts	4	3500.00 ET Birr	Diploma (10+3)
Team leader	2	5000.00 ET Birr	Diploma (10+3)
Senior GIS expert per woreda	1	6000.00 ET Birr	Diploma (10+3)
Woreda coordinator per woreda	1	7000.00 ET Birr	Land Administration degree or LA 5 year experience (10+3)

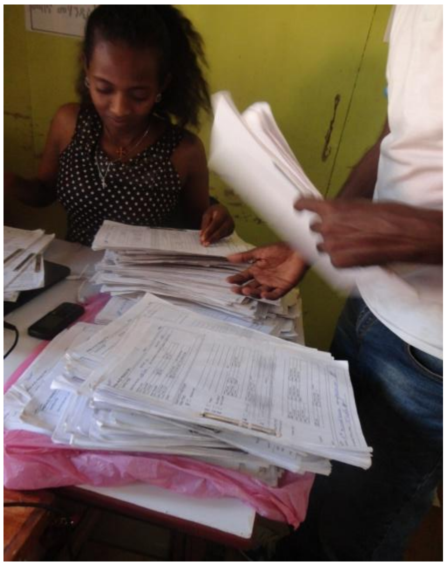
APPENDIX 11

Fieldwork Photos

Field Surveyor using Collector for ArcGIS

Data capturing with new method (mobile app) and current methods (orthophotos)

Field measurements with Collector for ArcGIS & R1



Digitizers organizing field forms

Field surveyor taking notes during field