3.3: FIRST EXPERIENCES WITH HIGH-RESOLUTION IMAGERY-BASED ADJUDICATION APPROACH IN ETHIOPIA

CHRISTIAAN LEMMEN, University of Twente, Netherlands
JAAP ZEVENBERGEN, Delft University of Technology, Netherlands

SUMMARY

Great progress has been made with rural land certification in Ethiopia. This process, however, has been mainly confined to the first phase certificates – those without a georeference. In 2008, a team conducted a simple field test using high resolution imagery. On-site tests were performed to determine if Quickbird satellite imagery could be used to establish parcel index maps in selected villages. The data collection in the field was performed with the help of land rights holders and local officials. The image quality of the plots at a scale of 1:2000 was sufficiently high to allow the parties to easily understand the images and contribute input, making the process very participatory. Many land rights holders were not able to present their certificates, suggesting updating issues. Even though the test was not well prepared, it yielded useful experiences and data. This limited data set was processed initially with ArcGIS and later with the first prototype of the Social Tenure Domain Model (STDM), which is open-source software. Processing the limited graphical display of the boundaries was relatively easy, but trying to link the data to Global Positioning System (GPS) coordinates (collected, at the same time, with hand-held GPS) was not immediately possible due to offsets caused by a number of reasons. Nevertheless, the approach seems very useful for lower land value areas where coverage is more important than (absolute) accuracy.

INTRODUCTION

Since the beginning of the 21st century, great progress has been made with rural land certification in Ethiopia. Several Ethiopian states have introduced land administration systems for rural areas aimed at issuing land use certificates at an affordable cost for all (sedentary) farmers in that state. Unlike many similar initiatives in other countries, the implementation of this quickly caught on in Ethiopia, and by 2005 data had been collected on about six million households, about half of which have actually received their "first phase" certificates. These certificates identify the landholders (by name, etc., and with photographs), but are weak on the description of the land plots, which include neither a map nor any kind of spatial reference (except for a list of neighboring landholders) and only give a roughly measured or estimated indication of acreage.

To gain more of the benefits that land administration can bring, graphical and/or geometrical data on the spatial units to which the landholders have their (eternal) use rights need to be collected. After adding such spatial plans, some speak of second phase certificates, although very few have been issued to date. In practice, it is possible to combine the issuance of first and second phase certificates.

The fact that large areas are being covered (and soon all rural landholdings in several states) makes it possible to have a real effect on the way land is administered and managed in those states. This differs from the "advanced" cadastral and registry approaches that, even after many years, often only extend to certain pockets of territory. For details on the procedures applied and the effects see e.g., Deininger et al. 2006 and Deininger et al. 2008.

In a number of places, with support from different donors (Swedish International Development Agency (SIDA) and the U.S. Agency for International Development (USAID)), the regional land administration authorities have used GPS and Geographic Information System (GIS) to collect and process boundary surveys. In July 2008 a team (partly overlapping with the authors of this paper), did a first simple field test in the Tigray and Oromia states using high resolution satellite imagery as a base for data collection. This limited data set was later processed using ArcGIS software, and has been re-processed using the first prototype of the Social Tenure Domain Model (STDM). In early 2009, further testing was done by the Environmental Protection Land Administration and Use Authority (EPLAUA) in Amhara as part of the Cadastral Index Mapping piloting (Belay 2009). Comparable work includes earlier doctoral research in Ethiopia (Haile 2005), ongoing doctoral research in Pakistan (Zahir 2009), as well as pilot projects in Rwanda (Sagashya and English 2009) and Namibia (Kapitango and Meijs 2009).

The field tests of July 2008 in Ethiopia, the processing of the data collected, and some recommendations for ways forward are described in the next sections.

DATA COLLECTION

Acquiring Imagery

Using satellite imagery for cadastral applications is not new.[2] Only of late are images available with resolutions that make them useful for standard-size land parcels (spatial units). Satellite images have, for a long time, been used for applications on large pastoral ranges and forest reserves. A quick scan of Quickbird satellite images led to the conclusion that it would be possible to acquire satellite images for a number of villages (*kebelles*), the lowest level of local government, in four different regions at 60 cm resolution which were nearly cloud free. We chose the true color, with pan sharpening (see figure 3.19).

Given the size of the data set (as well as the costs), it was important to acquire only the images covering the area needed. Digital contours of the *kebelles* were obtained from the Central Statistic Agency of Ethiopia (CSA) and could be used to select and order the required images from a private company (Digital Globe). This still amounted to 5.8 Gb of data. The base price was US$17 per km^2, and the original choice led us to acquire 26+32+39+61 km^2.

Overview plots of each region were made and used to define the exact test area, making sure a mix of terrain and land use modalities were incorporated. For a part of the *kebelles*, large scale plots representing a size of 1 x 1 km in the field were plotted on a 1:2000 scale on paper of sufficient quality for field data collection. The 1 x 1 km grid square was then drawn in red on the paper plot. The real area represented on the paper plot was bigger to allow for drawing in parcel boundaries (spatial units of lands in use by persons) intersected by a grid line (see figure 3.20).

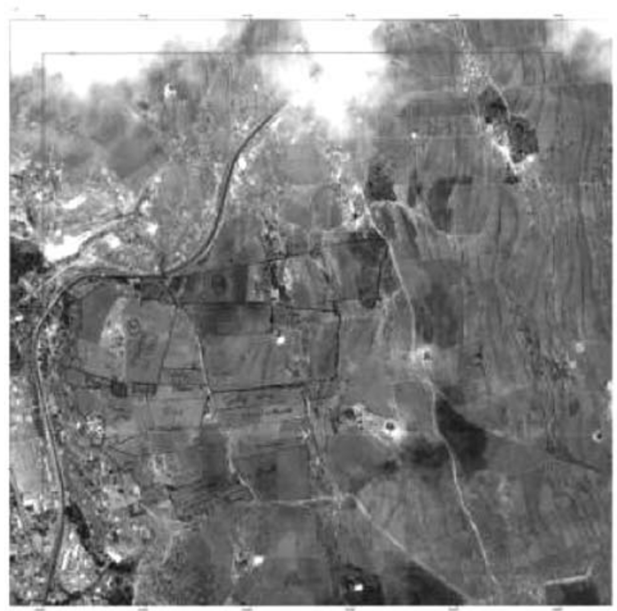
Informing Local Communities

The local communities were informed in advance of the data collection exercise. Individual rights holders, as well as community representatives, were asked to be available on site. The rights holders were also asked to bring their (first level) certificates.

2 Kansu and Sezgin (2006); Konstantinos (2003); Paudyal and Subedi (2005); Tuladhar (2005); Ondulo and Kalande (2006).

FIGURE 3.19: Quickbird Image Fragment

FIGURE 3.20: Raster Data of Hanigodu-Megelta with Parcel Boundaries, Identifiers and Names of Parcel Owners



Fieldwork

Fieldwork was carried out in early July 2008. Local district (*woreda*), the second level of local government, staff accompanied the team members to different locations (Hanigodu, Megelta, and Alengu) to aid with data collection. Land rights holders present in the field were invited to identify the boundaries of the land in use both in the field and on the paper plots. Land rights holders, neighbors, and community representatives participated in boundary identification.

The spatial units of boundaries were drawn on the plots by pen (see figure 3.21). Additional information collected included the name of the land rights holder of the parcel (or spatial unit), the certificate identification, the area, and the names of neighboring land rights holders to the north, east, south, and west. This additional information was to be used as administrative data and was written on (nonstandardized) papers. Different methods were used by different teams for the identification of spatial units and for linking the identified spatial units on the plot:

- By writing the name of the land user (this name was used as a link to the administrative data),
- By plot identification as given on the certificate, and
- By coordinate identification combined with a coordinate list (for the teams using hand-held GPS devices).

Local *woreda* staff took over the fieldwork activities for one of the teams after about an hour. It was evident that most of the participants quickly understood the images. They recognized where they were and even noticed changes between the present field situation and those at the time the images were made. For example, when looking for a small, irrigated plot in Tigray, the trees were counted, then people started to laugh when they realized that one tree had been chopped down in the meantime. Similarly, a number of water storage facilities that had appeared black (full) on the image, were now empty.

Although, during the informing of the local communities, land rights holders had been asked to be present with their land certificates, many of them did not show a certificate to the teams. Some said they did not have one, or that it was in an office for updating. Others mentioned that the family member who held it was presently not living on the land, etc.

In some areas, the boundaries were easy to recognize on the enlarged plots. These types of boundaries appeared as paths and looked like "general boundaries" (see figure 3.22). In other areas, the boundaries were more difficult to identify. They looked as if the boundaries had "moved" when

FIGURE 3.21: Drawing Boundaries on a Satellite Image

FIGURE 3.22: "General Boundaries": Easy to Identify on the Enlarged Satellite Image

FIGURE 3.23: "Moving" Boundaries

compared to the image. Creative ways to plough may have been the reason (see figure 3.23).

Lack of Absolute Accuracy

The images were not related to ground control points. This implies that the absolute accuracy is (according to Digital Globe, the provider of the images) up to 14 meters horizontal accuracy (root mean squared error) and 23 meters vertical. Orthorectification would improve this, but for "absolute pixel accuracy," ground control points are needed. A small sample orthorectified afterward showed differences of -20 meters on mountains and +40 meters in valleys. The NASA Shuttle Radar Topographic Mission (SRTM) was used as a digital elevation model for this. According to NASA, for regions outside the United States, the latest SRTM set is sampled at 3 arc-seconds, which is 1/1200th of a degree of latitude and longitude, or about 90 meters (295 feet).

Lessons from Similar Recent Tests

Similar tests held in Rwanda and Namibia concluded positively on the use of satellite images and aerial photos for land administration purposes. Sagashya and English (2009) performed a field test in Rwanda using satellite images and aerial photos. They refer to the simple methods of boundary demarcation on satellite images and aerial photos, which is a low-tech approach that costs about US$10 per parcel . After year five of first registration and titling, the subsequent recurrent costs are estimated at less than $1 per parcel in urban areas and $3 in rural areas. Kapitango and Meijs (2009) report on land administration in the communal areas of Namibia by the Ministry of Lands and Resettlement (MLR), together with the Communal Land Boards (CLB). In their paper, they present an approach where aerial photos have been used to fast-track the process of land registration. They conclude that by these means the registration process is now proceeding eight times faster than when undertaken with hand-held GPS units. They further conclude that the method is also more accurate, less prone to mistakes, more cost-effective, and more accessible. It also saves processing time.

DATA PROCESSING

Processing of the data involved scanning, georeferencing, digitizing, and feeding the fieldwork attribute data to the digitized parcels.

Scanning

This resulted in six analog images, each containing the identified boundaries and parcel-identifiers, which were scanned using a Cougar 36 scanner with 30 dpi resolution as a first step in transforming the field information in to a digital environment. Scanning resulted in six raster data sets in JPEG format. Necessary corrections such as rotations were carried out in order to ease the following processes.

Georeferencing

The six raster data sets contained undefined spatial references. Spatial references were defined by importing the coordinate system and projection of the original image. After defining the reference system, georeferencing was then performed by identifying and matching the coordinates of the new images (marked at the edges of each scanned image) with the original image. Control points such as road intersections and other identifiable features were also used. Figures 3.24 and 3.25 show an overlay of the scanned and georeferenced photographic images against the original image.

Digitizing

Once the images were georeferenced, on-screen digitizing was performed in ArcGIS. Parcel boundaries were extracted by pointing and tracing the cursor along the parcel boundaries drawn on the image. Each parcel was created as a closed

FIGURE 3.24: Georeferenced Images from Hanigodu-Megelta Overlaid on Original Image

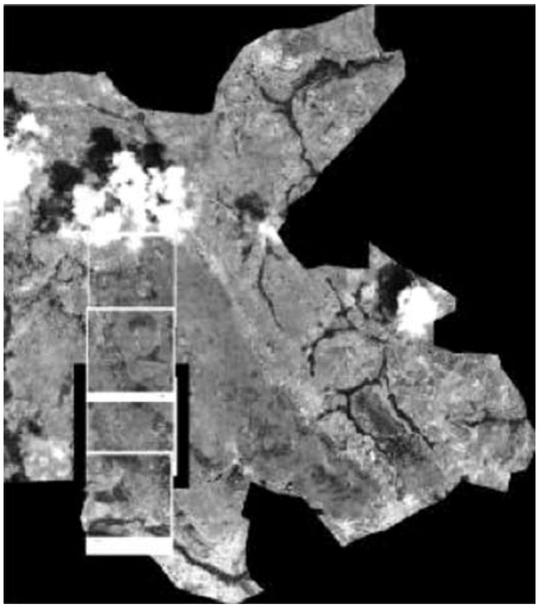


FIGURE 3.25: Georeferenced Images from Alengu Overlaid on Original Image

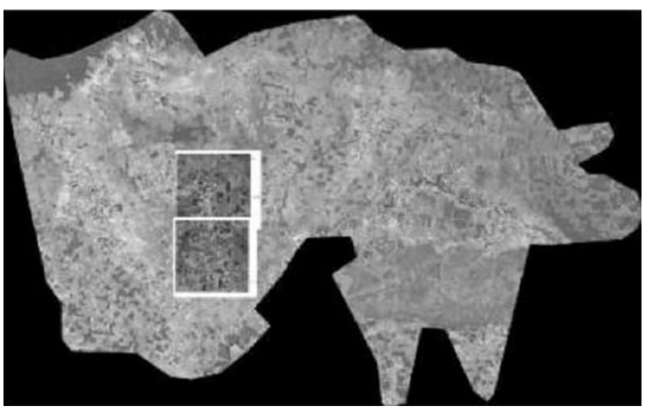


FIGURE 3.26: Digitized Parcels Shown in Red Lines in ArcGIS

polygon. The polygons do not share boundaries with neighboring parcels and are, therefore, independently identifiable. The digitizing process tried as accurately as possible to avoid overlaps between boundaries, especially where parcels bordered each other (see figure 3.26). This process resulted in parcel boundaries in shapefile[3] format. Two shapefiles were created: one from Hanigodu-Megelta, and another from Alengu.

Linking Field (Administrative) Data to Spatial Units in ArcGIS

A database containing administrative data about the attributes of the parcels was created in Microsoft® Excel® and was exported and joined with the attribute table of the parcel's shape file.

The results were that parcels (geometric data) now also contained administrative records, i.e., the names of the land rights holders of the parcels, their certificate identifications, the area, and the names of neighboring land rights holders to the north, east, south, and west (see figures 3.27 and 3.28). The information was successfully uploaded into the STDM prototype.

Using GPS Positions to Collect Evidence from the Field in Identification of Locations of Parcel Boundaries

GPS points consisting of survey points from the edges of various parcels in the field were uploaded and superimposed on the shape files. They were examined for mismatches between the GPS positions and corresponding parcels (see figures 3.29 and 3.30).

It was observed that the

- GPS positions displayed suffered from both vertical and horizontal offsets,
- Vertical offsets were greater than the horizontal offsets, and the
- Parallel/diagonal offset is about 200m.

These offsets are likely caused by the fact that the images were not orthorectified and by errors introduced during scanning and georeferencing processes (see figures 3.24, 3.25 and 3.31), as well as by relief distortion resulting from the differences in elevation of the aerial images and the GPS observations as described above. A more comprehensive

3 A shapefile is a commonly used data format for GIS software that spatially describes features depicted on a digital map as geometric shapes (e.g. points for water wells, lines for roads, polygons for parcel boundaries).

FIGURE 3.27: Attributes of the Parcels Are Linked to Parcels

FIGURE 3.28: Parcels and Attributes Identified Using "Identify" Icon in ArcGIS

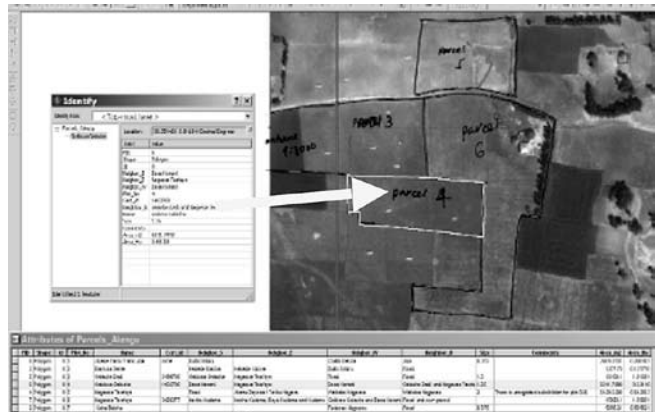


FIGURE 3.29: GPS Positions Overlaid to Image

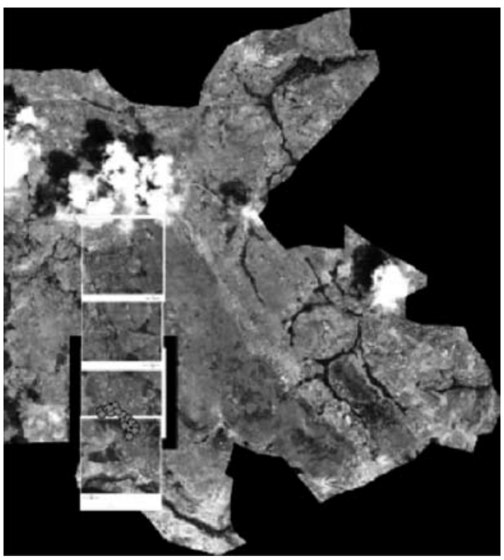
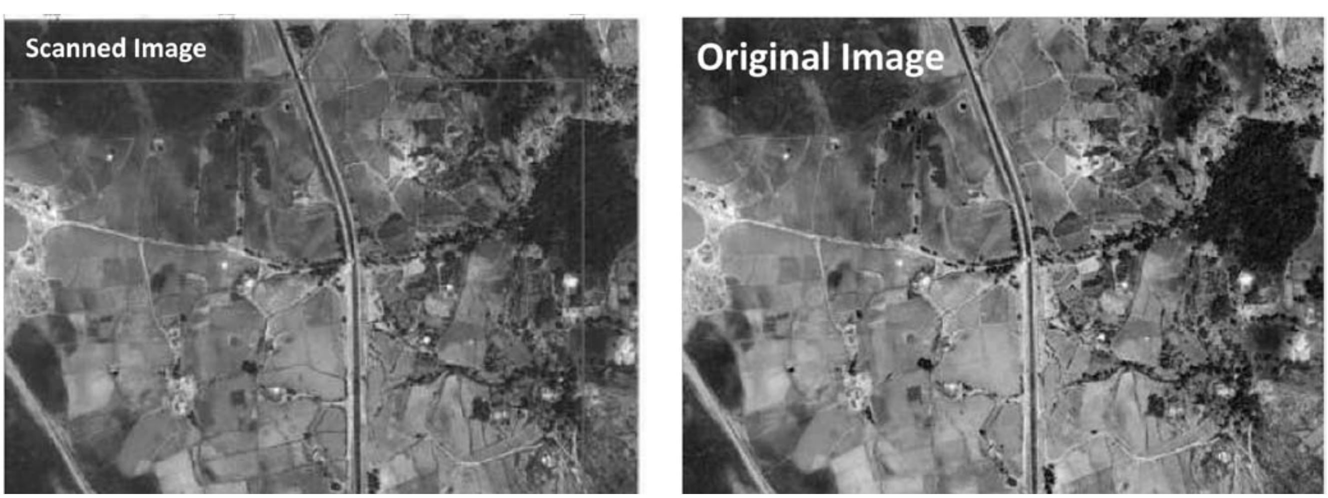


FIGURE 3.30: Offset of GPS Positions from Parcel about 200m

FIGURE 3.31: Scanned and Original Image



analysis for more and less mountainous areas has been recently undertaken in Pakistan (Zahir 2009).

Reprocessing with the STDM Prototype

In the same period as the data processing just described, the first author was heavily involved in work on the prototype of the STDM. The STDM is a pro-poor land administration tool intended to cover land administration in a broad sense, including administrative and spatial components. Conventional land administration systems relate names and addresses of persons to land parcels (or spatial units) via rights. In the STDM, an alternative option for this is to relate a personal identifier, such as fingerprints, to a coordinate point inside the land in use by that person, via a social tenure relationship. Depending on the local conditions, there can be a variety of social tenure relationship types and other rights. The STDM thus provides an extensible basis for an efficient and effective system of land rights recording. The STDM is seen as a specialization of the Land Administration Domain Model (formerly known as the Core Cadastral Domain Model) of the International Federation of Surveyors (FIG). (See Augustinus et al. (2006) and Lemmen et al. (2007)) It is based on the principles of Free/Libre/Open Source Software.

The STDM development so far entails the making of a conceptual, functional, and technical design, and starting software development with a prototype.[4] When the STDM prototype became available for testing in the beginning of 2009, the data collected in July 2008 was entered as a first test, resembling a field test.

In STDM-enabled land administration, data coming from diversified sources is supported based on local needs and capabilities. This pertains to both spatial and administrative (nonspatial) data. For example, it may be used in informal settlements, sufficient as a start, to relate people-land relationships to a single point. Then attributes such as photographs and fingerprints can be attached to the records. In areas of high market value, a traditional cadastral map and register may be required, while elsewhere land administration needs may entail using a map derived from satellite images, combined with formal descriptions of rights and rights holders. The STDM encourages and caters to all these variations.

4 This prototype is developed by the International Institute for Geo-Information Science and Earth Observation in a project in co-operation with UN Habitat. This project was announced during the fourth session of the World Urban Forum, held in Nanjing, China, November 3–6, 2008.

High resolution satellite imagery is one of the emerging and promising sources of spatial data for this type of land administration. A large-scale plot of such images can be used to identify land over which certain rights are exercised by the people themselves, i.e., in a participatory manner. The data collected in July 2008 fits this approach. This data has been inserted into ArcGIS as previously described and has been reprocessed in the STDM prototype in the beginning of 2009 for internal testing. Even with this limited amount of data, the reprocessing was done successfully (see figure 3.32). The testing was continued in a more extensive field test in late August 2009 in Bahir Dar, Amhara. The STDM's user interface proved to be simple and the prototype could be used in a flexible way. The software requires improvements to be more stable, which, in principle, is outside the scope of prototyping and a step toward real systems development. During the field test, a proof of concept for using satellite images for land administration based on open source software was delivered.

FIGURE 3.32: Presentation of Parcels (Shown in Dark Lines) in ILWIS/Postgres[5] Based STDM

LESSONS LEARNED

From the field test and processing done in 2008, the following was learned:

- People can read the satellite images easily. Almost without exception, the local people could easily recognize on the paper plot the area and buildings where they were living and the land they were using. For the data collectors, it was easy to record the location of the boundaries of land in use as agreed between the

5 Free open source software that can be used to create and store GIS and remote sensing data.

neighbors on site directly onto the printed satellite images. In some cases, when neighbors were not on site, data collectors observed that people tended to claim extra land. An alternative approach may be to bring a Personal Digital Assistant (PDA) to the field to present the satellite image on a screen (see Palm 2006). This implies that the screen data must be readable even in sunshine. Costs could be saved because there would be no need for plotting and scanning as the parcel boundaries could be vectorized[6] directly onto the orthoreferenced satellite image using the PDA. Whether such an approach has the same perception of validity as collecting evidence from the field or not should be tested.

- The approach is a participatory approach. The paper plots are attractive, and people are surprised by how much they see and recognize. The paper plots are something "to sit around and to work with," especially for illiterate people. The same may be valid for an alternative setting where a village community is invited to identify boundaries in a room where the satellite image is projected on a wall, as was tested in early 2009 in Amhara (Belay 2009). But this will not produce the same level of evidence from the field as walking around the land in use.
- In most cases, boundaries can be easily identified on the satellite images, especially when small paths are in use to access the lands, which creates a type of general boundary. Sometimes people demarcate the boundaries, but this is not always the case and in some areas the boundaries are "flexible" and move during the different seasons. Clear differences between the boundaries observed on the images and the field situation have been observed in cases of such "flexible boundaries." The ease of identifying boundaries on the satellite images may depend on the weather conditions present on the day of the satellite observation in mountainous areas (see Zahir 2009). Of course, clouds present during when the images were captured will affect the clarity of the images and their usability for this methodology.
- The data are available in a homogeneous reference framework. However, the accuracy may not be comparable to conventional systems in, for example, Europe. The approach allows for the reconstruction of individual points within a certain standard deviation in case of boundary disputes later in time.
- It is easy to get lost in some field environments: GPS for orientation purposes may be a requirement to be investigated.
- Relatively speaking, checking administrative data takes a lot of time. Data collected during the fieldwork was incomplete and contained many errors, especially where the names of people are concerned. The same names were collected several times resulting in data duplication and interpretation errors because the same names appeared in different spellings. If no spatial data can be produced, this method is an option to describing the location of a spatial unit, but there is a risk of errors and extra processing time because of this.
- In some cases, the ink disappeared from the images used in the field. A good marker and other equipment is vital. For a comprehensive test, the following issues need to be tackled in time:
  - Paper type (costs and volume in large scale applications)
  - Paper size (e.g., A3); overlap areas are presented on paper
  - Ink to draw boundaries in relation to weather conditions
  - Thickness and pen color (to draw straight lines on the image using a thin pen point)
  - Possible impact for archiving, such ason scanning the images of the images and then vectorizing the collected spatial data in post processing
  - Symbiology in drawing (e.g., to mark a deleted line)
  - General approach in identifying objects, such as using lines around the parcel, this means no individual point identifications. Name of the user directly drawn on the image? Or a temporal plot identification (related to the data collector)?
  - In short, a more systematic approach, but we are aware of that, of course, and much can be learned from earlier work with aerial photographs.

CONCLUSION

The use of satellite images to support the collection of spatial data for land administration is participatory, produces field evidence, and is relatively easy to process. There are processing concerns about scanning images with drawn boundary data on it, georeferencing and digitizing the boundary data, and referring administrative data to spatial units.

6 Recorded ditigally using vector-based GIS, which is comprised of lines or arcs and depicts features on the map using their boundaries (see the footnote on "shapefile" above).

Accuracy depends on the quality of the image, whereby very mountainous or cloudy areas result in reduced accuracy. Accuracy further depends on the plot structure, whereby visible boundary features, and a coherent parcelation to improve accuracy.

The approach fits with land administration concepts like those behind the Social Tenure Domain Model and affordable Cadastral Index Mapping, as well as when coverage is more vital in the short- and medium-term than decimeter precision (as it was identified by the relevant government officials during the fieldwork reported in Zahir 2009).

The earlier identified lack of updating of rural land certificates was noticeable through the fact that many land rights holders did not have their certificates with them in the field. Most likely, second-level certification work will largely include redoing the first-level work to some extent as well. Even the current digitalization of first-level certificate data includes a new posting for public inspection after the entry of each kebelle. First- and second-level certificates could be easily combined in a non-certificated area.

REFERENCES

Augustinus, C., Lemmen, C. H. J. and van Oosterom, P. J. M. 2006. Social Tenure Domain Model Requirements from the Perspective of Pro-poor Land Management. In: proceedings of the Fifth FIG Regional Conference for Africa: Promoting Land Administration and Good Governance, Accra, Ghana.

Belay, Gebeyehu. 2009. The Procedure Followed and the Results Achieved from CIM Piloting. Presentation at the International Workshop on Cadastral Index Mapping, Bahir Dar (Ethiopia). (online at World Bank: http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTARD/0,,contentMDK:22196904~pagePK:148956~piPK:216618~theSitePK:336682,00.html)

Deininger, Klaus, Jaap Zevenbergen, Daniel Ayalew Ali. 2006, Assessing the Certification Process of Ethiopia's Rural Lands. Colloque International, At the Frontier of Land Issues: Social Embeddedness of Rights and Public Policy, Montpellier, France.

Deininger, Klaus, Daniel Ayalew Ali, Stein Holden, and Jaap Zevenbergen. 2008. Rural land certification in Ethiopia: Process, initial impact, and implications for other African countries. *World Development* 36(10):1786–1812.

Haile, Solomon Abebe. 2005. Bridging the Land Rights Demarcation Gap in Ethiopia: Usefulness of High Resolution Satellite Image (HRSI) Data. Dissertation, BOKU, Vienna, October.

Kansu, Oguz and Sezgin Gazioglu. 2006. The Availability of the Satellite Image Data in Digital Cadastral Map Production. XXIII International FIG Congress: Shaping the Change, Munich, Germany.

Kapitango, D and M. Meijs. 2009. Land Registration Using Aerial Photography in Namibia: Costs and Lessons. FIG-WB Conference. Land Governance in Support of the Millennium Development Goals: Responding to New Challenges. World Bank, Washington, D.C.

Konstantinos, Christodoulou. 2003. Combination of Satellite Omage Pan IKONOS-2 with GPS in Cadastral Applications. UN/ECE WPLA Workshop on Spatial Information Management for Sustainable Real Estate Market Best Practice Guidelines on Nationwide Land Administration, Athens, Greece.

Lemmen, C.H.J., C. Augustinus, P. J. M. van Oosterom, and P. van der Molen. 2007. The Social Tenure Domain Model: Design of a First Draft Model. In: FIG Working Week 2007: Strategic Integration of Surveying Services. Hong Kong SAR, China. Copenhagen: International Federation of Surveyors (FIG).

Ondulo, Joe-Duncan and William Kalande. 2006. High Spatial Resolution Satellite Imagery for PID Improvement in Kenya. Shaping the Change, XXIII FIG Congress, Munich, Germany.

Palm, Lars. 2006. Comparison of Total Station/Advanced GPS Survey and High Resolution Satellite Imagers. The National Conference on Standardization of Rural Land Registration and Cadastral Survey Methodologies. https://webmail.itc.nl/exchange/lemmen/Inbox/Re: Your paper-2.EML/ - _ftn1#_ftn1. United Nations Conference Centre, Addis Ababa, Ethiopia.

Paudyal, Dev Raj and Nab Raj Subedi. 2005. Identification of Informal Settlement by Integration of Cadastral Information and Remote Sensing Satellite Imagery. A Seminar on Space Technology Application and Recent Development In Geospatial Products in Kathmandu, Nepal.

Sagashya, D. and C. English. 2009. Designing and Establishing a Land Administration System for Rwanda: Technical and Economic Analysis. FIG - WB Conference, Land Governance in Support of the Millennium Development Goals: Responding to New Challenges. World Bank, Washington D.C.

Tuladhar, Arbind Man. 2005. Innovative use of remote sensing images for pro-poor land management. FIG Expert Group Meeting on Secure Land Tenure: New Legal Frameworks and Tools, Bangkok, Thailand.

Zahir, Ali. 2009. Second Fieldwork Report (Part 2), Assessing Usefulness of High-Resolution Satellite Imagery (HRSI) in GIS-based Cadastral Land Information System. Internal Report, ITC. November. (unpublished).