Using Ortho-Rectified Imagery to Delineate Land Rights

Cleotilda Nxumalo[1], Jennifer Whittal[2] , Xolani Xaba[3]

[1]Chief Directorate: National Geospatial Information. Department of Rural Development and Land Reform, Cape Town, South Africa
[2]Geomatics Division, University of Cape Town, Cape Town, South Africa, Jennifer.Whittal@uct.ac.za
[3]Chief Directorate: National Geospatial Information. Department of Rural Development and Land Reform, Cape Town, South Africa

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Abstract

In South Africa, the former apartheid land policy resulted in uneven distribution, development and management of land in South Africa, especially in rural areas. One of the main areas of redress for the Department of Rural Development and Land Reform (the Department) is the restitution and redistribution of land. A huge challenge faced by the Department is the demarcation of vast tracts of un-surveyed land parcels in rural areas. This is where the professional land surveyor plays a vital role. There is a need to test remote surveying techniques as a means to increase efficiency in parcel surveys and hence speed up the process of land reform in rural areas. This paper investigates the use of high resolution ortho-rectifed imagery to identify land parcel boundaries in a case study of Giyani in rural South Africa.

1. Introduction

Rural cadastral systems in South Africa has had limited development and over the years a significant vacuum in spatial information has been created. Differences between former homelands and urban areas in terms of land administration, especially in cadastral data maintenance/ completeness/currency have emerged due to South Africa's fractured history. While the urban areas of South Africa boast a world class cadastral and land management system (Fourie, 2002), the former homeland areas have been seriously neglected. Formal cadastral systems are not in existence and land administration has followed traditional and customary structures plus processes causing a duality (Nxumalo, 2013). Since the birth of the democratic state in 1994, the government of South Africa has been faced with the challenge of amalgamating these cadastral systems. The directive by the Department of Rural Development and Land Reform (DRDLR herein referred to as the "Department") is to formalise the cadastral system in rural homelands and bring it on par with the modern systems of the urban cadastre.

The Department of Rural Development and Land Reform seeks to redress the injustices created by the Native land Act of 1913 and subsequent legislation. Since democracy in 1994, legislative reform has led the transformation of the land sector. One such Act, the Communal Land Right Act

(Act 111 of 2004, called CLaRA), was passed to provide for legalized tenure in communal rural areas. It is believed that the Communal Land Rights will exacerbate the problem in land tenure especially in former “homelands” (Cousins, 2002). In 2010, the Constitutional Court declared CLaRA unconstitutional. Questions arose for the Department of Rural Development and Land Reform as to what would replace the controversial Act. In a statement by Minister Nkwinti, the Spatial Planning and Land Use Management Act (SPLUM Act 16 of 2013) fills this need for legislation in communal land rights (Nkwinti, 2013). However, the Minister has indicated that an additional bill relating to institutionalized communal land rights will be addressed with “very broad” consultation (*ibid*).

Inferior titles to land have been successfully upgraded in urban areas. However, that is not the case in rural areas making up the former Apartheid “homelands”. Communities in non-commercial rural areas in South Africa comprise close to 2.3 million households (Perret, 2001). Many of the dwellings lie on State land and are un-surveyed. The occupants have no formal individual security of tenure or title deeds (Cousins and Hall, 2011). However, delivery of the land reform programme is too slow (*ibid*) and is lately being used as a tool by populist politicians (Nkwinti, 2013). The Department has been instructed to accelerate cadastral data collection surveys in order to achieve security of tenure for rural communities. Parcellation of rural land as part of the redistribution and restitution objectives of the land reform programme is a significant task.

Even though many rural properties in traditional and former “homeland” areas were not registered in the Deeds Registry, the traditional communities and their leaders have practiced their own form of the communal land rights administration. The desire to formalise customary rights and the land parcels to which they refer has been expressed by communities and the government alike (Interviewee 2, 2012). Most community members are enthusiastic about receiving some form of proof (or confirmation of ownership) to their own land.

Figure 1. Giyani Fenced houses

Across rural South Africa physical evidence of land demarcation is clearly visible in communal areas (Figure 1). Fences and hedges are indications of the extent of the land people consider as their own. Most of the occupants of these dwellings are in agreement with their neighbours that the physical features are the common boundaries demarcating different land rights. Therefore, these physical features are recognized as the primary evidence of boundaries and are socially-accepted methods of demarcating rights.

As new surveying technologies emerge, they are applied to improve development processes. Aerial photography has been available for many decades, and the potential use of remotely sensed data for cadastral purposes has often been mentioned in South Africa, particularly since the end of apartheid and the start of the land reform programme (Bujakiewicz, 1988, Fourie, 1994, Barry and Ruther, 2005). The Chief Directorate: National Geo-spatial Information (CD: NGI) has the mandate to acquire aerial imagery as a State function and so this data is already available. Internationally, aerial imagery has long been touted as effective in supplementing and augmenting traditional survey methods (Ali et al, 2012). The identification of land parcel boundaries through the use of remote sensing has been recommended in many countries (e.g. Afghanistan, Pakistan, Nigeria and Cambodia) as a cost-effective technique for land titling (*ibid*). The incorporation of GNSS and remote sensing with digital aerial photography offers further benefits in positioning (Tuladhar, 2005). However, serious testing in a cadastral environment has not yet been undertaken in rural areas and it is still unclear whether the use of remote surveying techniques could meet the requirements of cadastral surveying both in practice and in terms of current legislation.

The aim of this study is to test the use of integrated technologies in a pilot case study of the villages in rural Giyani, South Africa. Data to be used in combination for the location of cadastral boundaries are high resolution ortho-rectified aerial imagery, remotely sensed imagery and GNSS centimetre-level data. The usual cadastral data obtained from the Offices of the Surveyor-General and the National Geospatial Information Offices (NGI of the Department will also be used. If this study shows that the technology is useful to supplement and fast track land redistribution and restitution in this real pilot case, it could be more rigorously tested for general determination of cadastral subdivision boundaries for land registration in rural areas in South Africa. A pilot study covering the villages in rural Giyani will be undertaken to find a viable, efficient and effective method to address the absence of cadastral data in former homeland areas.

2. Method

This paper is a single pilot case study in order to test a technical method of remotely surveying rural land parcels in South Africa. As such, general theory of land tenure and information systems underpins the research (Barry and Roux, 2012) as well as case study strategy (Yin, 2003) and the tools and techniques of cadastral land surveying and legal requirements. The research follows general experimental design in order to:

- determine the optimal spatial resolution of imagery required to identify boundary features (in the rural communal context) in South Africa former homelands,

- determine the suitability of imagery to identify boundaries and other rights
- identify limitations of ortho-rectified imagery as a basis of determining these rights
- make recommendations on the use of ortho-rectified imagery for cadastral applications in the stated context.

3. Theory

Cadastral surveying is the process of gathering and recording data about land parcels, whether it is for an existing cadastre or a new land parcel (Dale and Mclaughlin, 1999). Cadastral systems are one of the basic building blocks of land administration systems (Enemark, 2005). A cadastral information system is a set of data collection systems for the processes on land parcels. This includes land tenure, land value and land use. The recording of land rights in a land registry provides security of ownership as well as attaching integrity and a unique identification to each land parcel (Williamson et al, 2010). The cadastral description has two forms. One is in the form of a plan depicting shape, size and location on the ground. The second form is a land register that records ownership, rights, surface area and other land parcel-related information (UNECE, 2005). These two descriptive information sets are dependent on cadastral surveying for the capture of land boundary information. The primary function of cadastral surveying is to delineate land units on the ground for the purpose of recording rights in a land register.

Land administration is the process whereby land policies are executed within a broader land management system (Enemark *et al*, 2005). It includes the procedures and techniques for systematic collection, updating, processing, and distribution of the data to the end users in an efficient manner (Ali *et al*, 2012). A complete and current database of spatially referenced land information is an essential element for effective land administration (*ibid*). Globally, a number of initiatives to develop land tenure systems are applied to address challenging land titling, especially in developing countries. Examples of these initiatives include the Social Tenure Domain Model, Open Titler, and open source packages such as the UN-FAO SOLA, Land Tenure Titling system and the Land Administration Domain Model (Barry *et al*, 2013). However, even these initiatives are designed to address specific scenarios with specific challenges (*ibid*). To address the strategies of land reform and land tenure in South Africa, an evolutionary and flexible land information system requires the replacement of rigid rules and procedures that are inappropriate in addressing the pitfalls of titling in rural South Africa. The exploratory investigation in the use of ortho-rectified imagery to identify physical land parcel boundaries appears to be an accessible alternative to conventional land boundary identification applications. It could be a simple method to identify and measure the extent of land rights using remotely captured geo-spatial data. It could be used for the large scale registration of land parcels in rural South Africa.

Advances in remote sensing and processing of remote sensing imagery, as well as developments in geographic information systems and database management, may improve the effectiveness, efficiency and maintainability of land administration systems (Aleksic et al, 2005). The implementation of these technologies presents opportunities for maintaining and sharing land information in a more seamless manner. Currently, acquisition of cadastral information in South Africa is mostly undertaken by surveyors in the field. Survey methods result in the identification of the boundary beacons and establishing their coordinates on the South African National Coordinate System (Parker, 2011). Global Navigation Satellite Systems (GNSS) and theodolites are commonly used technologies. However, to carry out these field surveys in remote, rural and mountainous areas can be challenging, time consuming and expensive.

4. Pilot Case: Giyani

4.1 Choice of case study area

In 2008, the African National Congress (ANC), the political party in government, held a national conference in Polokwane. There they resolved the need to reinforce rural development. Later, the resolution translated into policy and hence action in rural development.

A specific pilot project area was selected by the Minister of Rural Development and Land Reform (DRDLR) for the Comprehensive Rural Development Programme (CRDP). This was motivated by a newspaper article the Minister read detailing the levels of poverty in the area. The President then pronounced the status of Giyani as a pilot area for CRDP in Parliament. A team was deployed by the DRDLR for the implementation of the project and to hold discussions with Provincial stakeholders. The project team focused on the processes of rolling out development initiatives in line with policy directives at National, Provincial and Local government level and in line with the pronouncement of the President.

4.2 Geographical Location

Giyani is located at 23 18’ 36” S and 30 42’ 23” E, situated in the Province of Limpopo (Figures 2), which is the northern most province of South Africa. The town falls under the Greater Giyani municipality in a rural area on the Klein Letaba River.

Figure 2: Map of Limpopo Province and five study areas

Five villages (Figure 2) in the Giyani municipal area, namely: Ka-Siandana, Ka-Dizingidzingi, Ka-Homu, Ka-Ngove and Ka-Mapayeni, were selected so that the variety of different dwelling patterns found in Giyani could be investigated. The only form of tenure found in these villages is Permission-to-Occupy (PTO) which is issued by the Chief (see figure 3).

4.3 Current means of acquiring land in rural Giyani

Should an individual require land in Giyani, customary processes are followed. The land beneficiary (Figure 3) consults the Chief in writing. The Chief undertakes research on the background of the land requested and decides whether the applicant is worthy of land rights (Informants 1 and 2, 2012). The case is then passed from the Chief to the Induna (headman). The Induna does the ground work of allocating the land as well as introducing the new land occupier to his/her neighbours and the community. After the Induna is paid for his service by the new occupier, a PTO is issued (Informant 4, 2012). In the case of land occupation for business rights (Figure 3), there is an additional process whereby Municipal approval is also required. Payment for leasing land for business rights is owed to the Chief and Municipal property tax (called “rates”) are also due to the Municipality by the business. This is an example of the duality of authority in these areas whereby the business owner interfaces with both formal municipal requirements and the customary requirements (*ibid*). When PTO’s are issued the land is not surveyed or demarcated. The PTO is only a paper-based authorization to occupy the land. Because there is no registered ownership, development is impeded.

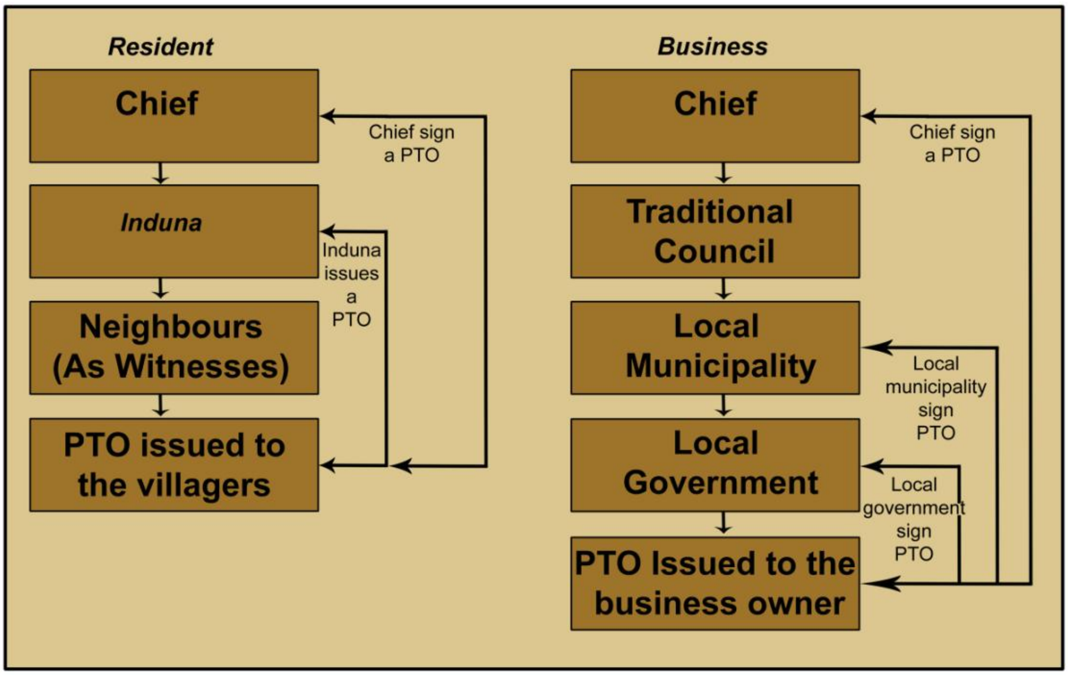

Figure 3: Acquisition of land rights in Giyani

4.4 Parcel sizes

In earlier years, families in Giyani villages were issued with 3 hectares of land by the Chief. The land use was divided into farming, grazing and residential uses. However, due to population increase and gradual change from rural to urban uses along with concomitant loss of interest in farming, the size of land issued gradually decreased. Currently, land parcels of 28m x 28m (784 square metre plot) are allocated for residential use only (Informant 2, 2012).

4.5 Boundary demarcation initiatives

The Chief instructs the villagers to fence their land before taking occupation as the means of boundary identification and to avoid later disputes. Some initiatives were taken by the Municipality and the Department of Agriculture to demarcate boundaries with wooden poles (Informant 2, 2012). However, the land has never been registered as the processes do not conform to the requirements of the Land Survey Act (No 8 of 1997) and the Deeds Registries Act (No 47 of 1937), which govern the registration of formal land parcels in South Africa.

4.6 Legal requirements

It is a huge task to demarcate close to 2.3 million individual land parcels using conventional field survey techniques. Section 8 (6) of the regulations promulgated in terms of Section 10 of the Land Survey Act (No.8 of 1997) which deals with curvilinear boundaries, states that "Photogrammetric methods may be used for determining the position of any curvilinear boundary: Provided that the annotation of such boundary on an aerial photograph or orthophoto map shall be done in the field." Currently, the Regulations do not make provision for the use of aerial imagery or orthophoto maps for surveying rectilinear boundaries. Legislative changes will need to be made should such methods be considered for surveying and registration of land parcels in South Africa.

4.7 Use of photogrammetry under SA law for cadastral survey

Surveys are conducted in accordance with the Surveyor-General's Manual of Procedures (Chief Surveyor General, unknown date), the Land Survey Act (No 8 of 1997) and related Survey Regulations. The Regulations of the Land Survey Act (No 8 of 1997) provide scant direction to the practitioner wishing to conduct cadastral surveys using ortho-rectified imagery. Regulation 3 (1) specifies that surveys shall be conducted in accordance with limits of accuracy specified in Regulation 5. However, there are none in Regulation 5 which relate to this method of survey. It is probable that Class B accuracy specifications apply since surveys of settlements are contemplated. Class B specifications are $1.5m \times \frac{0.04+S}{30\ 000}$ with S being the distance to the nearest known point. This is equivalent to 5mm if the known point is 100m away and 5cm if 1km away. Known points in the ortho-rectified imagery used in this investigation are about 15km away from the cadastral points surveyed. This translates to 0.75 m accuracy at Class B level. Since the specifications for these Classes were not compiled with such distant known points in mind, it is doubtful whether the SGO would accept diagrams framed with such low levels of accuracy. It is thought that Regulation 5(b) may override this accuracy:

> *5(b) When the position of a beacon in a township is checked by the measurement of distances from adjacent beacons, the difference between a single measured distance and the*

adopted final distance shall not exceed 0,10 metres: Provided that for surveys carried out in terms of the Upgrading of Land Tenure Rights Act, 1991 (Act No 112 of 1991), the Less Formal Townships Act, 1991 (Act No 113 of 1991) and when a permanent physical feature is being fixed as a beacon the difference shall not exceed 0,20 metres

Regulation 5(b), however, refers to relative inconsistencies in adjacent beacons rather than accuracy of position in the South African Coordinate Reference System. It also refers to erven in a township and not those in peri-urban or rural areas. There is certainly lack of clarity as to target accuracies for cadastral surveys using photogrammetric methods.

Regulation 3(e) provides for photogrammetric methods and the stated technical specifications can be complied with. The provision that the land surveyor must positively identify the positions of points on the photographs, has relevance. Regulation 8(6) states that, when photogrammetric methods are used to survey a curvilinear boundary, annotations of the boundary on the aerial photograph or orthophoto map shall be undertaken in the field. This, by omission, does not include straight line boundaries and point positions for beacons. Regulation 11(1)(ii) states that posts may be adopted as beacons if the fence is "properly erected" and that a corner of a building must be adopted as a beacon when it coincides with the boundary corner position. Both of these features may be visible from aerial photographs.

4.8 Rectified images with the GSD of 0.15m and 0.5m

The NGI realised the benefits of acquiring digital imagery and invested in the purchase of a digital aerial camera. Aerial imagery has been digitally captured with this DMC camera since 2008. The Ground Sample Distance (GSD) has replaced the traditional photo-scale method of determining image resolution. The GSD is the size of 1 pixel on the ground and is influenced by the flying height and focal length (CD:NGI 2010). The images are captured with a GSD of 0.5m, in 12bit RGB (true colour), near infra-red and panchromatic. The digital images are stored as JPEG compressed Tiff files with a full set of overviews. Images with a GSD of 0.5m cover an area of approximately 7.0 km by 3.8 km on the ground. The images are ortho-rectified to eliminate distortion and are then mosaiced to create 1:10 000 scale orthophotos. However, the resolution has limitations of feature identification for cadastral purposes.

In 2010, the Giyani images were captured with a GSD of 0.15m also in 12 bit RGB. Images with a GSD of 0.15m cover an area of approximately 2.0km by 0.6km on the ground. Feature identification is much more reliable and accurate with the higher resolution images and this could be suitable for the identification of existing land parcel boundaries. Figure 4 is an example of a rectified image at 0.5m resolution. In comparison, Figure 5 represents a rectified image at 0.15m resolution of the same area.

Figure 4: 0.5m GSD imagery

Figure 5: 0.15m GSD imagery

In figures 5, property fences and boundary lines are more clearly visible than in figure 4 which is at a lower resolution. Most community members confirm that the fences are their property boundaries and they express their satisfaction that the fences may be recorded as the boundary lines (Interviewee 6, 7,8,10, 2012).

4.9 Realistic accuracy

In their study, Barnes and Eckl (1996) examined the accuracy requirements for cadastral surveying that generate data that is low cost, efficient, simple and appropriate. They focused on the purpose of coordinate information that results from a cadastral survey. They adopted the following which were cited as main purposes of coordinate information:

- to relocate the physical monument that demarcates the corner position,
- to replace a missing corner monument in the event that it has disappeared,
- to describe the land parcel (diagram in the case of South Africa) for transaction purposes.

The accuracy required to support these functions will in turn depend on several factors including parcel size, land value, land suitability for specified uses and relationship between neighbours. Barnes and Eckl (1996) suggest that an accuracy of less than 1 metre is appropriate, when considering low land value and low commercial agricultural use such as for small to medium sized land parcels typical of rural areas. In order to meet the sub-metre accuracy level, certain specifications with regard to equipment, measurement tolerances, field survey and computations must be followed. In conclusion, it was stated that current digital imagery should be considered for cost-effective map production in developing countries such as are proposed by Schuur, (2004).

4.10 On-site interviews

During February 2012, survey personnel from the NGI, comprising the first and last authors, met up with various chiefs, Indunas and community members from the different villages in the case study area of Giyani. The objective was to investigate the views of community members, traditional leaders and Municipal representatives on the state of land boundary demarcation. In order to gain legitimacy in a rural customary community in South Africa, correct protocol must be followed.

The approach was, firstly, to inform the Municipality about the project so that they would hear about it first-hand and also so that they could pave a way for the researchers to address the traditional leaders and the community.

According to the Municipal representative, land demarcation is necessary for the development of communities. In addition, they stated that it would contribute to the available spatial data and in turn assist in spatial planning, development processes and assist in service delivery and ultimately poverty alleviation (Interviewee 4, 2013). Currently, many rural municipalities do not have adequate land information systems and therefore face difficulties in spatial planning of rural areas. Many municipalities claim that their relationships with traditional leaders have deteriorated because of the clashes between traditional and municipal authority on community matters (Nxumalo, 2013). The introduction of policies and processes regarding land matters will need to be introduced delicately.

The traditional leaders in rural areas have reservations about the benefits of registered individual tenure and feel that this move may have a negative impact on the community (Interviewee 3, 2012). The traditional leaders agree that land tenure could assist in the development and service delivery processes. However, their reservations are based on the fact that ownership tenure by the poor may result in community members being vulnerable to the exploitation of their assets (*ibid*). One interviewee mentioned that financial institutions would voluntarily offer credit against the surety of land if the land rights were registered (Informant 14, 2012). Furthermore, traditional leaders are concerned that their authority over the community will diminish with the introduction of individual ownership. The current system of PTOs authorises the traditional leader to distribute land between the people of the community. However, no records are kept as the allocation of land rights relies on communal processes and social memory as well as social acceptance (Interviewee 5, 2013).

The majority of community members in Giyani are enthusiastic about registered land ownership (Interviewee 4, 2013). Their optimism is displayed when they offer their services during the field work. However, many are unaware of the significance of land tenure upgrading. Some of the landholders seem uninterested in land tenure transformation and feel that it has no effect on their daily lives (Interviewee7, 2013). Others still prefer the PTO system as they are loyal to the King and are concerned over the consequences of a system change (Informant 9, 2012). An alternative view is that the fee paid for PTOs and the additional service fees attached to this tenure is just part of a money-making scheme by the traditional leaders (*ibid*) and should be stopped. In general, there is consensus that land ownership will give people a sense of belonging and allow them to contribute to the development of the country.

4.11 Field surveying

Once all stakeholders were briefed on the proposed project, preparations were made to carry out the GNSS field surveys using RTK GPS. Survey control was identified from Survey Record

886/2005 in the Office of the Surveyor-General. The communal land parcel boundary corners were surveyed using a centimetre-level accuracy dual frequency, RTK GNSS. The occupation time at the corner points was 12 seconds. The land parcels had no erf numbers or street addresses. This made the naming of the boundary beacons challenging. For the purpose of the pilot case, parcels were named alphabetically and beacons were given alpha-numeric names.

Only a fraction of the pilot case study area was surveyed for the purposes of this research. Based on the findings of this research, a method of surveying the land parcels will be chosen and rolled out country-wide and include the completion of the survey in this area. Ninety corner boundary features were identified and surveyed. Y and X co-ordinate value tolerances of less than 0.03m were achieved for the RTK GNSS surveyed points. The RTK GNSS coordinate accuracy meets the specifications in South African law.

4.12 Coordinates from Aerial Imagery

Back in the office, boundary corner points were digitized from 0.15m GSD imagery using Arc GIS 10.1 at a scale of 1:300m. The high resolution of the rectified images allows for features to be enlarged to the extent that the actual fence corner is clearly visible. Figure 6 shows the plotted (at a scale of 1:300) GNSS RTK surveyed points (yellow circles) and the digitally geo-referenced points (cross hairs) of the same fence corners.

Figure 6 Surveyed land parcel demarcation corners

5. Discussion

The field survey combined with survey using ortho-rectified imagery was the maiden attempt to identify, collect and analyse data in the pilot area for the purpose of a comparative analysis of the accuracy of measuring land parcel boundary corners in areas such as Giyani. The RTK GNSS coordinates were adopted as the true co-ordinates. This allowed for assessment of the suitability of the scaled-off coordinates from the ortho-rectified imagery for cadastral purposes (see figure 7).

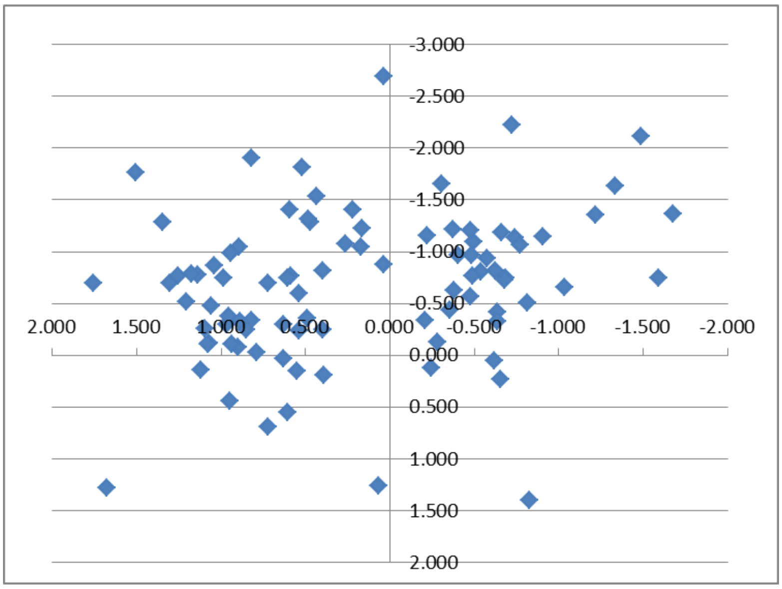

Figure 7: Scatter plot of imagery coordinates around the true positions

Figure 7 shows the differences between the ortho-rectified imagery coordinates and the RTK GNSS coordinates for the 90 points in the test data. The standard deviations are 0.82 m in y and0.72 m in x. The maximum offset of the image point from the true coordinate is 2.69m while the average offset is 1.19m. The averages of the ordinate offsets are 0.19 in y and -0.62 in x. This indicates a possible bias of the data which could be due to the rectification process. This bias is applied to the dataset as a shift in y and x, hoping that the georeferencing of the image coordinates improves. Thereafter the maximum offset of the image points from the true coordinates reduces to 2.45m while the average offset reduces to 0.98m. Thus only a marginal improvement is achieved by shifting the data by the apparent bias.

6. Conclusion

High resolution ortho-rectified aerial imagery with a resolution of 0.15m should enable features such as wire fences, hedges, low walls and other boundary documentation to be identified and their coordinates digitized. The process of rectification, identification of boundary corners, and digitizing was expected to yield results at the sub-metre level, in accordance to the study of Barnes and Eckl (1996) as stated in section 4.8. Seventy-six percent of the results (as shown in figure 7) were within this accuracy and of the order of Class B cadastral requirements (Regulation 10 as discussed in Section 4.7). Unfortunately, twenty-four percent of the results reported do not meet the requirements of sub-metre accuracy as per Barnes and Eckl (1996). This indicates that the use of high spatial resolution aerial imagery in the manner conducted in this pilot study is not adequate to for cadastral boundary coordinate determination since the specifications were only met for ¾ of the points in the case study. Furthermore, the maximum offset of close to 2.5m is way outside the acceptable accuracy and even the average offsets at around 1.2m indicate that this technology is not yet suitable for the task at hand.

7. Recommendations

At this stage, the use of ortho-rectifed imagery as a land rights tool in rural areas is limited to visual identification of land parcel extents, dwellings, out-buildings etc. Such data could fulfil a role in resolving land disputes and encroachments. Photo interpretation skills, obtained through experience, are a vital aspect when using ortho-rectifed images in any sort of land rights work. Community participation is recommended as an additional stage in confirming any features identified as indicatory of land extent.

One of the major concerns identified during the reconnaissance was that the traditional leaders do not totally support full ownership as it clashes with their traditional means of land administration. An alternative may be communal or usufruct land rights. The use of ortho-rectifed images as a tool to register land rights in rural areas needs to be investigated further. In particular, the process of rectification and feature identification and digitizing should be reviewed to ascertain whether, with the current technology, greater accuracy can be achieved.

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Interviews

Sources are protected for reasons of confidentiality. In a number of cases more than one reference number is associated with one interview or confidential correspondence to prevent revelation of sources. A list of informants cross-referenced to these codes is retained in the possession of the principal researcher.