ADOPTING "*First-level Adjudication*" INTO A GIS MEDIUM

A Preliminary report for AFRA by Denis Rugege, March 2005

Participatory mapping

G I S

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1 INTRODUCTION

1.1 Background to and justification of the project

This project is a component of the project "Piloting of Local Administration of Records - PILAR", undertaken by the Association for Rural Advancement (AFRA). AFRA is an independent land rights NGO that aims to redress past injustices, to secure tenure for all and to improve the quality of life and livelihoods of the rural poor. Pilar's main objective is to assist the people of Ekuthuleni obtain legal, affordable and accessible land records in order to improve their tenure security and their access to credit and municipal services. Spatial representation of these land records in form of a "General Plan[1]" (a Communal General Plan in the case of communal lands) is a key requirement in the process. Figure 1below shows a flow

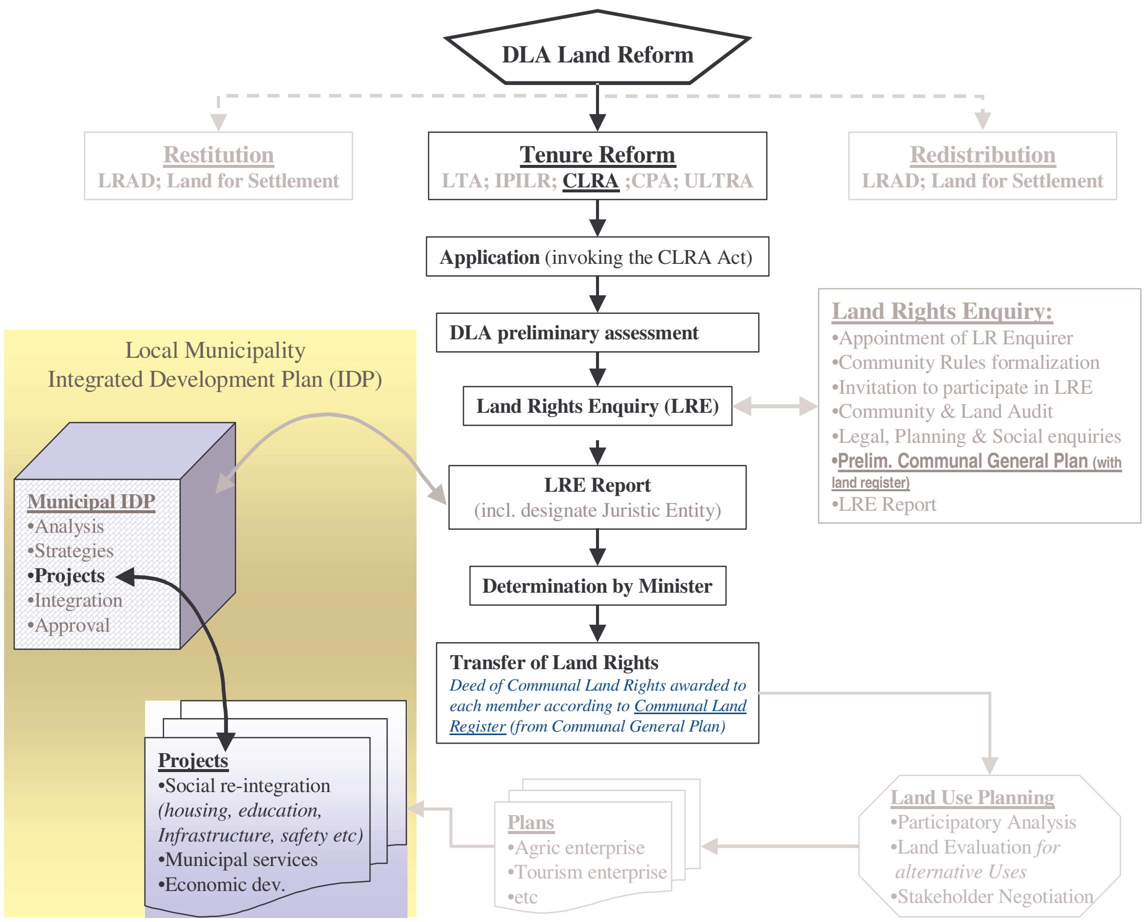

Figure 1 Communal Land Rights Act implementation procedure

[1] A General Plan as defined in the Land Survey Act No. 8 of 1997 is required for registration of land whenever subdivision of land into two or more parcels is carried out.

diagram of implementation procedures of the land tenure security reform as interpreted by the Communal Land Rights Act (CLRA) No. 11 of 2004. CLRA is intended to provide a policy framework and policy instruments for implementing the required land tenure security in the communal lands of South Africa.

One of the instruments in implementing CLRA will be the formalization, through the Land Rights Enquiry (LRE), of "community rules" of land administration in recognition of informal systems. The advocacy for the decentralization of land administration by formalization of the informal communal land administration systems have up to the enactment of CLRA been well argued by Leisz (1996), Fourie (1996), Fourie and Gysen (1996b) in Hodson (2004). The main point of argument is that access to land information such as liquidated estates, deceased estates, maps, land use zoning, registration and marriages is not equitable as it is only available through central offices.

However, land information in the centralized formal system is based on products of land surveys such as survey diagrams and general plans. Communal lands in South Africa and elsewhere in the developing world are largely unsurveyed. It is generally accepted that the cost of surveying communal land is prohibitive and its effectiveness debatable as a basis for functional decentralized land administration system for the capital-poor rural residents (Hodson, 2004; Gartell and Hodson, 1997).

Various alternatives to conventional surveying as a basis for formalizing communal land administration have been proposed (Fourie, 1994; Jackson, 1996; Fourie an van Gysen, 1995 in Hodson, 2004). These are described by Hodson (2004) and include:

- The "general boundary" method whereby local authorities subdivide land basing on boundaries agreed upon by neighbours. Lower precision surveys are then carried out without reference to beacons.
- The "mid-point" method whereby a single point in the centre of a property marked by a stake is registered and that it could be maintained in the Surveyor General's formalized system. A combination of the general boundary method and the mid-point method using a handheld low precision level (5 meter) Global Positioning System (GPS) may also be considered. In this method, the proponents propose that a mid-point coordinate would be obtained using the house as the physical evidence and relating boundary description to it. The problem with the mid-point approach is that dwellings are not always located in the middle of their respective boundaries. Dwellings may be located adjacent to each other, motivated by the need for neighbourliness. Some dwellings may be placed as close a possible to roads and other infrastructure. A 5-metre precision level GPS might not be appropriate for such residential conditions. However, higher-precision level (1-meter) handheld GPS have recently become available and their costs are expected to become affordable for capital-poor communities.
- The "Block and Super Blocks" method which would involve the accurate survey of a communal area within which lower precision and therefore cheaper subdivisions would be carried out. The outer blocks would be registered as diagrams at the Surveyor General and included within the national cadastre. According to Fourie (1994) this model would include the cultural norms and values of a variety of chosen community systems within the block. The cheaper

subdivision method within the block could be adopted from the general boundary, the mid-point or the combination of both methods.

A preliminary interpretation of CLRA suggests that this concept may applicable in its implementation. CLRA stipulates that Land Rights Enquirers will assist the communities in regularizing their land administration rules and in determining the Juristic Entity as the designated beneficiary to whom the land will be held in title and as custodian of their individual land rights. Ownership of communal "block" of land will therefore be transferred to the Juristic Entity. This may be comparable to the "Block and Super Blocks concept". The act requires that community rules be translatable into secure rights that gives that may be used as a basis for the Minister of Land Affairs to subdivide the "block" into individual land rights. However, CLRA also makes provision for individuals to upgrade their land rights to individual title though an application process.

Through the Pilar project, AFRA has attempted to test the "general boundary" concept using a participatory mapping activity with the Ekuthuleni community. A rectified large-scale aerial photograph (1:2000) was used together with household interviews to identify land and land-use-right holders and to create a land rights map with demarcated boundaries. The functioning local land administration system was described and documented and existing shortcomings and problems identified.

The main aim of this component of the Pilar project was to verify the accuracy of the participatory boundary demarcation exercise within the "first-level adjudication" process using Global Positioning System (GPS) and Geographic Information System (GIS) technologies. A literature study based cost-benefit analysis of using these technologies in the rural communal contexts would carried-out. The specific objectives of the study are outlined below:

2 STUDY OBJECTIVES

2.1 Capturing existing spatial data into a GIS medium

With the assistance of Pilar, Ekuthuleni inhabitants had drawn their land rights boundaries using permanent Koki pens on plastic transparencies overlaid on rectified large-scale colour aerial photographs in a participatory mapping process. The colour aerial photographs were also available in digital format. The land rights demarcations were digitised into a GIS format so as to integrate them with other spatial information.

2.2 Testing the viability of rectified large-scale colour aerial photographs in identifying and demarcating boundaries

A qualitative check on the accuracy of aerial photo interpretation by the participatory mapping group for land rights boundary identification and mapping was required to assess its viability.

2.3 Comparative cost-benefit analysis of GPS-based participatory GIS as a method of identifying and recording boundaries in an adjudication process

It is of crucial interest to have an idea of the cost-benefit ratio of using the abovementioned method for sustainability considerations and recommendation for wider use in land tenure security reform.

3 METHODOLOGY

3.1 Data collection and data capture

Boundary demarcations obtained from participatory mapping were digitised into a GIS format. A preliminary basemap for a Communal General Plan was prepared. Annex 2 displays a compilation of spatial features to make-up the basic framework for a Communal General Plan for Ekuthuleni.

Figure 2 A high accuracy hand-held GPS unit displaying rectified aerial photo as a background image map (left) and a vector map (right)

The six digital colour aerial photographs of Ekuthuleni were consolidated into a single rectified image mosaic. Annex 3 shows the consolidated image map. The consolidated image was entered into a GPS for use in fieldwork for the verification of the boundaries demarcated by participatory aerial photo interpretation. Figure 2 below shows the GPS with screen displaying a rectified aerial photograph of the study area as a background image map (left) and with a vector map (right).

3.2 Linking spatial data to land record descriptions

A sample of land rights was selected to test the accuracy of the boundary demarcation and also to test a methodology of confirmation and update of land right records using Ekuthuleni as a case study. The sample selection was based on an evaluation of the aerial photograph interpretation. Observations were made of interpretations that didn't seem to be logical. The suspect interpretations included odd boundary shapes that did not follow any features that the interpreting team would have used to draw the lines. Due to limited time and resources we could not implement a statistically viable random sample scheme. A representative selection of suspect cases was therefore opted for.

The next step would be linking the spatial representations of the land rights and associated descriptive records through a table in a GIS medium. This would enable the various users to visualise the spatial extent of land rights as well as the associated descriptive records in a digital Communal General Plan. In the next section, it is explained that not all the samples selected could be tested within the capacity of the study due to unanticipated field constraints.

3.3 Fieldwork

3.3.1 Rapid appraisal

The fieldwork started with a drive-around in Ekuthuleni in a rapid assessment of the area as well as meeting the Ekuthuleni land rights committee. The planned study was explained to the committee and the high-resolution (large-scale) colour aerial photograph that had been used in the boundary demarcation process displayed to them, this time in GIS environment on a laptop computer. The committee members were very interested in the concept of the study and volunteered to perform some visual interpretations themselves. They were able to point out their homesteads and their associated extents of land rights with ease.

3.3.2 Boundary verification using GPS

Annex 1 describes the boundary verification method and activities carried out subsequent to the rapid appraisal. During the appraisal, it was noted that the study area was very ragged with steep slopes and dense vegetation in places. Vleis occur frequently in the area. Walking the boundaries as the main method of boundary verification therefore turned out to be more challenging that initially anticipated.

After investigating four parcels, it was realised that many more persondays and travelling resources would be required to cover all the selected samples. In consultation with the Pilar project manager, it was decided that a preliminary report be prepared identifying important issues that would arise from the four cases and to make recommendations for a fresh proposal that would take into consideration the physical constraints of the area. The high accuracy (sub-metre) GPS described in section 3.1 was used to log walk-trails of the land rights boundaries investigated for the first three land parcels as described in Annex 1. Verification and confirmation of a fourth parcel was done by the Induna as part of a subdivision and land right allocation of land where the main land right holder and "ababhekiwe" were already living. A detailed description is given in the proceeding section.

3.4 Cost-Benefit Analysis

In order to determine the cost-efficiency of a GPS methodology as an alternative for conventional land surveying, it is necessary to design and test the GPS method and to compare it with conventional methods. As mentioned in section 3.3 earlier in this report, physical constraints of the study area limited what could be achieved in the available time and budget. For this reason, it was not possible to comprehensively test the designed GPS-based participatory adjudication, demarcation, surveying and mapping methodology and to carry out a parallel conventional land survey for comparison basing on a set of efficiency measuring criteria. It was therefore decided that the available resources be used to carry out a cost-benefit analysis for comparable circumstances based on available literature.

3.4.1 Cost and benefit categorization

Although it was not possible to test the GPS method against a conventional land survey method, an attempt was made to develop an understanding of the developed procedures and associated costs involved in both methods. The GPS based method was redefined and structured as recommended by Barnes et al (1996; 1998) in a flow diagram according to activity type.

The method begins with preparations and planning at the office base followed by calibration of the GPS unit, field procedures and a post-processing routine back in the office. The last step involves the submission of the survey records to the relevant authority, the Surveyor General in the case of South Africa. Brief explanations of these steps are provided in the next section under cost categories.

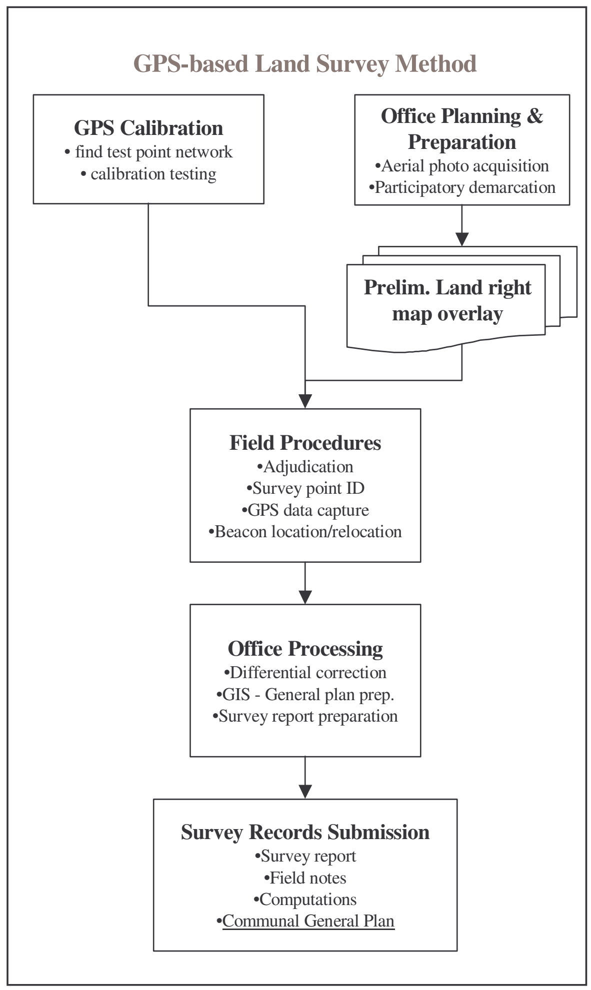

Figure 3. GPS-based participatory boundary adjudication, demarcation, survey and mapping procedure

GPS-based method cost categories

Table1 shows three main cost categories associated with the GPS-based method. These include establishment costs, recurrent costs time charges for relevant activities. Establishment cost include hardware composed of GPS units, software composed of GPS, computer operating system and GIS software. Recurring costs include services such as Internet access, GPS real-time or post-processing differential correction. Envisaged services would also include training of professional and technical survey personnel in participatory methods.

Although South African surveying profession is expected to be well conversant with GPS technology, it has not yet been adapted as an operational method. Total Station methods or Electronic Distance Measuring (EDM) methods are the main conventional cadastral land survey methods. Refresher courses may be required for operationalization of GPS-base methods. Time-based costs include procedural activities for conducting a survey.

Table 1 Cost categories of the GPS-based Land Survey method for the preparation of Communal General Plan

Establishment costs:	
Hardware	GPS units (<1m accuracy level) Computers (with Internet, database & mapping capabilities)
Software	GPS firmware/software Computer operating System GIS/database Software
Recurring costs:	
Services	Internet GPS Differential correction
Training	GPS refresher courses for Land Surveyors; Training in rural community participatory mapping methodology
Time costs: GPS Survey Procedure (modified from Barnes& Eckl, 1996):	
Office planning and preparation	Determining base stations to be used for differential correction Establishment of WGS84 control points GPS unit parameter configuration for meeting accuracy set data capture standards Creating a data dictionary for providing structure for data collection Acquiring rectified colour aerial photograph for survey area Participatory interpretation of rectified colour aerial photograph and preliminary demarcation of land rights
Calibration of GPS unit	Establishing calibration network (10 or more accessible points with accurately known coordinates for GPS unit calibration) Establish GPS unit accuracy (receivers, antennae, firmware, software) to meet set standard by regulating body Calibration testing for GPS unit precision (multiple baseline test; less than 1m) and (multiple occupancy test; less than 1.4m)
Field Procedures and Transport	Participatory reconnaissance for the survey site Ibandla adjudication and confirmation of preliminary demarcation of parcels GPS capture of survey points or monuments (including servitudes) Beacon location/relocation
Office post-processing	Backup of field data Acquisition of Base Station, Differential correction and accuracy tests Export of GPS data GIS/spreadsheet GIS data manipulation for General Plan mapping Survey report preparation
Survey records submission	Survey report Field notes Computations General Plan

<u>GPS-based method envisaged benefits</u>

The GPS-based method is aimed at achieving the following general improvements in effectiveness and efficiency of land tenure security by allowing:

- (Community participation guarantees transparency and therefore community confidence and quality control of adjudication and demarcation process (Onkalo and Lor, 2004; Lyons and Chandra, 2001)
- Community participation enables the regularisation of the *de facto* social land tenure system (that includes complexities of "community rules" for shared, mutually beneficial use rights) into a *de jure* land registration system (Deichmann and Wood, 2001; Fourie, 2002)
- Community participation that provides an opportunity for constitutional reforms such as gender equity in land rights into the regularised "community rules" social land tenure system
- More sustainable dispute resolution
- Community participation as a source of employment
- GPS configured lower accuracy of capturing boundary data following adjudication and demarcation means lower cost which allows a match between cost of land registration and tenure upgrade in security to match the value of the land, hence long-term affordability and sustainability of registration system

Conventional method cost categories

The South African Council for Professional and Technical Surveyors (PLATO) publishes a tariff of fees for its registered membership (PLATO, 2003). A summary of land surveying activities that may be charged fees for creation of Land Rights in Townships though lodgement of a General Plan was extracted and provided in Tabe2 below. This summary seems closest in analogy to the envisaged Communal General Plan as describe in CLRA.

The cost categories of the Conventional land survey method are largely similar to those of the GPS-based method as can be seen in the activities category in Table 1. The main difference would then obviously be in the equipment used and which in turn is dictated by the accuracy level demand. The Conventional method also does not need capitalization, as Land Surveyors should already be well equipped and adequately trained.

Table 2 Costing the Conventional Land Survey method for the preparation of a General Plan

Creation of Land Rights in terms of the Land Survey Act 1997 (Act No. 8 of 1997)

Creation of Land Rights in Townships, Subdivision of properties and Consolidation of properties

Professional fees (R360 to 630 per hr)	
Activities	Creation of Land Rights Travel time and distance on site Reconnaissance for the survey site Establishment of WGS84 Control Relocation of beacons in the field Setting up of new beacons Administration of cadastral rights Beacon relocation audit Calculation for new beacons Supervision of technical personnel and field assistants Drafting workplans, diagrams and general plans Consistency checks on plans Survey report Submission of survey records to Surveyor General in terms of regulations of Act 8/1997 and Liaison Field materials
Additional work	Servitude endorsement on General plan Subdivisions Creation of outer figure represented on General plan Creation of curvilinear boundaries Creation of servitudes Creation of powerline servitudes covering existing powerline structures
Abnormal circumstances (increasing or reducing fees)	Access to the site of survey Availability of trigonometrical beacons Geotechnical conditions Topography Connections to other beacons of the property Cost-effectiveness of township layouts Boundaries through party walls Garden walls, vegetation or buildings obstruct or assisting survey

The PLATO guidelines as indicated in Table2 also include a cost category "Additional work" which mainly entails the surveying and mapping of servitudes, curvilinear boundaries and outer boundary that constitute a General Plan. In the GPS-based method, this categorization in not necessary as this set of activities are integrated in field procedures and have no additional cost implications.

The cost category "Abnormal circumstances" that may increase or reduce costs is also does not have special consideration in the GPS-based method. This cost category is based on the time and effort costs associated with the manoeuvrability of the EDM equipment in conventional surveys. As GPS-based method is built on cost-effectiveness, the methodology designed includes hand-held units; this cost category does not apply. However, dense tree canopy and deep v-shaped valleys may affect GPS signal reception. It is for this reason that some Land Surveyors have adopted the use of the two methods interchangeably.

Conventional method established benefits

The Conventional boundary survey method is built on high accuracy of point and distance measurement and therefore enjoys a largely dispute free client base. It is also an established profession with regulated stands by legislation. The surveyed coordinates represent legal boundaries that may be integrated into a cadastre. It is therefore possible to create new legal boundaries cheaply from existing plans by calculating without surveying in the field (Hawerk, 1997).

3.4.2 Cost-Benefit review

Very few Cost-Benefit Analysis studies have been done on using GPS as an alternative to conventional cadastral surveying and mapping. These include Barnes and Eckl (19960, Barnes, Chaplin and Moyer (1998), Lyons and Chandra (2001) and Louw (2004), Schnuur (2004). Of these, Barnes and Eckl (1996) was the most comprehensive, designed and carried out to test the performance of GPS technology under controlled conditions of the University of Florida, USA in comparison with field tests undertaken in Albania and Belize. The experience of their tests was further used as a basis to develop standards, specifications and procedures for a new GPS-based approach to cadastral surveying and mapping.

Barnes et al (1996, 1998) used the following criteria for testing the GPS-based methodology for cadastral surveying and mapping:

Realist accuracy: *there should be a match between the cost for obtaining a particular level of accuracy level and the value of the land to be surveyed*
Speed: *there should be a significant time saving advantage*

- ***Cost:*** *there should be a significant cost reduction per unit survey area*
- ***Appropriate:*** *the technology should be adaptable to local surveyors and community participants*
- ***Simple field operation:*** *data collection procedure should be simple enough to allow for verification of field conditions*

Realistic accuracy

In their study, Barnes and Eckl (1996) examined the long-standing question under international discussion regarding the accuracy requirements for a cadastral surveying and mapping methodology that is low cost, more efficient, simple and appropriate. They refocused on the purpose of coordinate information that results from a cadastral survey. The following were sited 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 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. Basing on experiences from Belize and Albania, Barnes and Eckl (1996) suggest that an accuracy of less than 1metre is appropriate, when considering low land value and low commercial agricultural use suitability of small to medium sized land parcels typical of rural areas. In order to meet the <1m accuracy level, certain specifications with regard to equipment, measurement tolerances, field survey and computations must be followed. These specifications were summarized earlier in Table1 of this report; under GPS survey procedure as modified by Barnes and Eckl (1996).

Table 3. Visible spectrum imagery sources (modified from Schnuur, 2004 and Lyons & Chandra, 2001)

Platform	Imagery/System	Resolution	Imagery control method	Accuracy	Typical mapping
Satellite	Landsat	10m	Level 1 GPS	10-25m	1:50,000
	SPOT	5m	Level 2 GPS	2-5m	1:25,000
	IKONOS	1m	Level 3 GPS	0.4-0.8m	1:10,000
Fixed Wing Aircraft	1:24,000 Vertical Airphoto	0.5m	Level 3 GPS	0.4-0.8m	1:10,000
	1:12,000 Vertical Airphoto	0.25m	Level 4 GPS	0.01-0.04m	1:5,000
	1:3,000 Vertical Airphoto	0.06m	Level 4 GPS	0.01-0.04m	1:1,000
	LiDAR - Low resolution	0.3m	Level 4 GPS	0.01-0.04m	1:5,000
Helicopter	1:1000 Vertical Airphoto	0.02m	Land survey-EDM	<0.01m	1:500
	1:600 Vertical Airphoto	0.01m	Land survey-EDM	<0.01m	1:200
	LiDAR - High resolution	0.05m	Level 4 GPS	0.01-0.04m	1:500

Current digital imagery and other surveying systems in Table3 that should be considered for cost-effective map production in developing countries are proposed by Schnuur (2004). The table shows a range of digital imagery, their sources and spatial resolutions, the appropriate level of accuracy when using a GPS-based or a Land Survey-EDM for control measurements as well as the appropriate scale of the final map product. The various GPS measurement methods have been simplified into 4 levels corresponding to different accuracies as presented by Schnuur (2004).

Table 4: Basic levels of GPS accuracy (Schnuur, 2004)

GPS "Level"	Description of GPS measurement method	Accuracy
Level 1	Standalone Pseudo-range GPS Positioning	10-25m
Level 2	Differential code GPS, or "DGPS"	2 -5m
Level 3	Carrier smoothed differential code GPS	0.4 -0.8m
Level 4	Double differential carrier phase GPS	0.01-0.04m

From the tables, two cost efficient methods are suggested for surveying endeavours that would enable the preparation of a Communal General Plan using the GPS-based method at an accuracy level of less than 1m:

- Final map at 1:5,000 scale produced using a 1:12,000 scale digital aerial photograph (or 1:10,000 orthophoto available in South Africa) for preliminary participatory demarcation and for the subsequent adjudication, boundary confirmation and mapping using a "Double Differential Carrier Phase" GPS. The 0.25m spatial resolution of the aerial photograph indicates that objects as small as 25cm in real size are discernable by the human eye on the aerial photograph. This means that narrow linear features such as open footpaths, streams, fences as well as other small sized features like individual rural dwellings may be interpreted during participatory mapping.
- Final map at 1:10,000 scale produced using a 1: 24,000 scale digital aerial photograph for preliminary participatory demarcation and for the subsequent adjudication, boundary confirmation and mapping using and using a "Carrier Smoothed Differential Code" GPS. The 0.5m spatial resolution of the base photograph means that objects as small as 50cm are discernible and can be interpreted by a participatory mapping team. However, the 1:24 000 scale photographs are not readily available in digital format in South Africa. Acquisition of aerial photographs for rural surveying is relative expensive.

The third method that can produce a final map at an accuracy level of <1m is the use of the IKONOS satellite imagery as base data. The image has a spatial resolution of 1m, which is still good enough for participatory interpretation and mapping. However, the imagery is relatively expensive (at around US$3, 000 a scene) for the envisaged purpose. It should however be noted that the acquisition of the satellite imagery costs a much as aerial photo acquisition but with among other advantages, having much larger area coverage in a single image.

Time and Cost efficiency

Three studies have reported on time and cost efficiency of the Conventional Land

Table 5. Time and Cost efficiency: Conventional Land Survey Vs GPS-based Land Survey

Author	Reference country	Cost Comparison
Barnes et al (1996; 1998)	Albania	2 times more productive
Lyons & Chandra (2001)	East Asia	2.5 times higher
Louw (2005)	Namibia	3 times higher

Survey method against the GPS-based method (Table5). Barnes and Eckl (1996) reported the comparison in terms of productivity rates in Albania, finding the GPS-based method twice as productive in the field and 7-8 times more productive in the office. Lyons and Chandra (2001) reported the cost of the Conventional method to be 2.5 times higher in Asian countries while Louw (2005) found the Conventional method to be 3 times more costly in Namibia.

Appropriateness of methodology

Modern education and training programmes in surveying are striving to strike a balance between the measurement science component and the broader aspects associated with land administration and land information management (Barnes et al 1998). Hodson (2004) suggest that the diversity of land tenure systems to be regularized and the pressure of finding more suitable cadastral systems will change the role of the land surveyor to a more diversified land management position. The University of KwaZulu-Natal has responded to this demand, offering a Masters in Land Management within the Surveying programme and a Master of Environment and Development in Land Information Management. Both programmes are dominated by participants with professional survey degrees and survey Bachelor of Technology degrees.

Also, South African land survey professionals are embracing GPS technology for standalone application or as integrals of Total Station/EDM systems. The former are also actively engaged in the Land Reform programme both at professional association and at individual levels. This positive situation will facilitate the smooth technological migration or integration of GPS-based methods.

Like most technologies, as time goes by, GPS equipment is becoming cheaper. However newer models offer higher accuracy and more functionalities and so prices stay in the same range. A handheld unit capable of <1m accuracy is currently costing about R18, 000.

Simple field operation

Barnes and Eckl (1996) described their data collection procedure during the field-testing of the GPS method in Albania and Belize as very encouraging. Their results showed that the method could be employed effectively with ease. The simplicity of the method is also indicated its being 8 times faster than the conventional method as mentioned earlier.

3.4.3 Conclusion

In the context of the imminent implementation of CLRA, a thorough and conclusive Cost-Benefit Analysis is necessary to allow for a decision to be made on the appropriate surveying and mapping method to be employed. Extensive field-testing of the method GPS-based survey method is required not only to compare costs with conventional survey methods but also to provide base data upon which a South African standard may be proposed. This analysis has shown that the GPS-based method has great advantages and potential in meeting the land registration needs of CLRA.

4 RESULTS

4.1 Preliminary Communal General Plan

The land right boundary demarcations were digitised from the overlay transparencies attached on each of the six pieces of aerial photograph. All road and access categories were digitised from the aerial photograph as well as other infrastructure and services such as power transmission lines and church and school respectively. A preliminary general plan map composed of property/land right identification numbers and their respective homesteads, roads, power transmission lines, school, church and drainage/stream lines was then laid out to form a basis for a Communal General Plan. Annex 2 shows the preliminary Communal General Plan for Ekuthuleni.

4.2 Nxumalo - Parcel No. 84:

The Nxumalo brothers (Figure 3) land rights boundary was selected because it was suspected that there had been a misinterpretation of the boundary features on the aerial photograph. It had been assumed that the boundaries drawn would flow visible line features such as roads, streams, fences or tracks and footpaths. In a verification exercise, the boundary was walked with the guide of the land right holders and the Induna. The GPS walk-trail seemed to correspond accurately where it was possible to walk along the boundary marker. In certain instances the boundary followed the

Figure 3 Nxumalo brothers outer boundary as demarcated using aerial photo interpretation (white) compared with a GPS walk-trail (red). Note that the boundary is mainly within the stream channel where walking as not possible.

stream and within wetland areas as well as within thick vegetation. We could not walk within the virtual boundary line as pointed out by the Induna because of these physical constraints. However the GPS trail showed that the aerial photo interpretation had been fairly accurate. Figure 3 shows the Nxumalo brothers boundary as demarcated (white line) compared with the GPS walk-trail (redline). The exercise confirmed that our assumptions in evaluating boundary demarcation based on aerial photographic interpretation had been wrong.

4.3 Nsele – Parcel No. 77 and neighbour Parcel No. 78:

Figure 4 shows the Nsele family land right boundary as demarcated by aerial photo interpretation in white lines and the GPS walk-trail in red. As can be seen, there are significant discrepancies between the two. It would seem that the aerial photo interpretation had followed the land cover change lines. The Induna, supported by the land right holder Mr Nsele and the neighbours (Nxumalo brothers) pointed out the correct boundary which included iron pegs driven into the ground. It is obvious that the first level community adjudication team could not depend on the iron pegs as they were invisible on the photograph but on the visible features they could use to approximate the boundary. The temptation to use the land cover change was the easiest way out. It should be noted that the land right holder is aware of the issue and had planted indigenous trees beside each iron peg as a visible marker for boundary identification purposes.

Figure 4 Nsele family land right boundary as demarcated by aerial photo interpretation (white line) compared with the GPS walk trail (red line). Note the boundary pegs along the GPS trail as pointed out by the Induna and logged in GPS.

4.4 Ntuli – Parcel No. 68:

Due to the constraints mentioned earlier, a different approach was tried out to address the issues raised around the Ntuli family land right demarcation that included a considerable number of "*ababhekiwe*". It was noted as a reasonable approach to ask the Induna to manually map (Koki pen) any land allocations he makes onto a laminated aerial photograph of the relevant area as an updating exercise. The Induna could also correct any erroneous boundary demarcations made by aerial photo interpretation.

In the Ntuli case Pilar was notified of an allocation or subdivision exercise that the Induna was to carry out on the Ntuli parcel in favour of the "*ababhekiwe*". The updated map was in-turn updated in the GIS. Figure 5 shows a comparison of the aerial photo interpretation demarcation of the Ntuli family land right in comparison

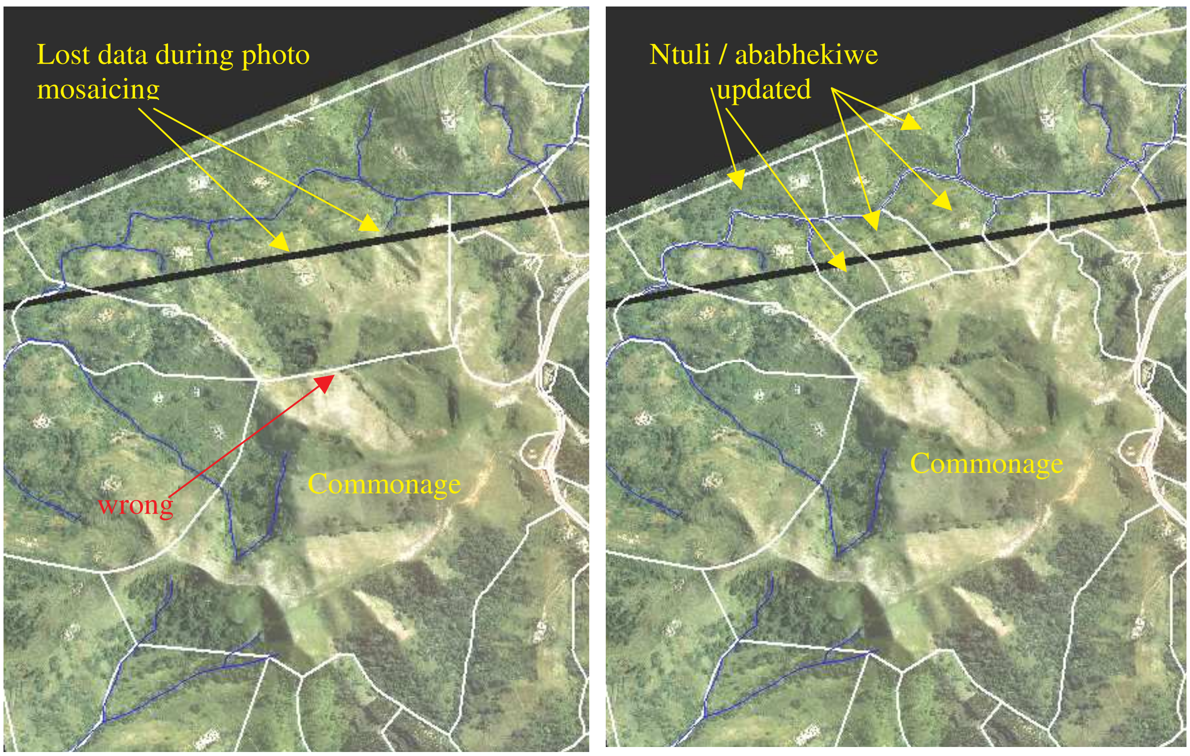

Figure 5 Ntuli family land right boundary by aerial photo interpretation (left) compared with the Induna's update (right)

with the subdivisions and boundary correction by the Induna.

Note is particularly taken with regard to the correction of the commonage boundary. It seems that the aerial photo interpretation had grossly underestimated the extent of the commonage. Reasons for this may be something other than physical and interpretive limitations such as opportunistic encroachment attempts on communal land by unauthorized annexing.

5 DISCUSSION

5.1 The rectified high-resolution/large-scale[2] colour aerial photograph as a tool for participatory mapping

Rectified, ortho-rectified (ortho-photos[3]) as well as unrectified of aerial photographs at various scales, in colour or panchromatic have been used beneficially as tools for participatory mapping tool for various purposes. Ortho-photos tend to be produced in panchromatic and at medium scales (1:10,000) and with added data such as contour lines. The density of information, the lack of colour and the scale together make interpretation rather difficult for a non-professional user. On the other hand, larger scale (1:2,000 – 1:5,000) colour aerial photographs that have been merely geo-referenced (not necessarily ortho-rectified) tend to be interpreted with ease by users from various backgrounds including individuals with low literacy or technical skills. This has been observed with the successful "first-level adjudication" process conducted with the people of Ekuthuleni.

In "first-level adjudication", large scale colour photographs are particularly advantageous for the following reasons:

- All inhabitants may participate individually as well as collectively, as each is able to recognize their environment remotely. This may be a powerful tool in dispute resolution
- Persons may be matched with homesteads or dwellings, making it possible to:
    - Start compiling a communal land register
    - Identify non-participation invoking a proactive approach
- Ability to integrate with other spatial tools as GIS and GPS for ease of updating

5.2 Disadvantages

Large-scale colour aerial photographs are not readily available. Often special orders have to be made for the area of interest to be flown at great expense with the context of rural communities as the purchasing clients.

Once obtained, digital formats need GIS expertise to manage for achieving the purpose already discussed. Education and training in land information management of key rural community members is therefore imperative. In addition, specialised GIS software and a computer with extended memory and storage features as well as a reasonable quality printer are required. Monetary resources are therefore necessary for developing land tenure security in rural communities.

5.3 Sources of error in participatory land right boundary demarcation

Although there clear errors in the boundary demarcation of land rights using the aerial photographs, the observations from the few cases checks seem to suggest that demarcations were accurate where natural and other *bona fide* features exist. Where

[2] High-resolution in the study describes the capability of displaying fine detail of objects in a digital aerial photograph whereas large-scale describes the similar capability but of a fixed scale printed map.
[3] Ortho-photos are georeferenced aerial photographs that have been rectified for distortions caused by aircraft tilt yaw and pitch during photographing flight.

streams (with associated terrain and vegetation) and other linear features such as fence lines, tree lines, trenches, footpaths mark boundaries, demarcations were accurate.

It was observed that incorrect aerial photo interpretation boundaries were demarcated where physical monuments such as invisible iron pegs had been used as boundary markers.

It was also important to note that the combination of GPS, digital aerial photography and local expert knowledge create an opportunity to rectify the identified error and update the boundary in question *in-situ* as shown in section 4.3 and figure 4. Errors may also be corrected or changes in land rights recorded on a hard copy which may be updated in a GIS at a later stage as conveniently possible, as was demonstrated in section 4.4 and figure 5. It is also possible to prepare an adjudication form and store it in GPS for prompting in the field while logging boundary information, provided that the appropriate adjudication team is present. Annex 5 shows an example of such a GPS digital form.

5.4 GPS limitations

It was noted that even the high accuracy GPS will lose the satellite signals in a deep v-shaped valley. However, although Ekuthuleni is largely ragged with steep slopes, deep v-shapes valleys do not occur frequently.

5.5 Implications for CLRA and other Land Reform policy instruments

Technology has now allowed the previously lacking geo-reference to maps produced by rural communities in participatory mapping processes. Participatory mapping exercises are increasingly done against a rectified background aerial photograph that will have usually been printed from a digital origin. The tool shows great potential in the sustainability of a land rights recording system as its visual properties allow it to be used not only by technical people but also directly by the affected individuals and groups. A combination of the GPS and GIS tools enhance the quality of participatory mapping processes for a wide range of possibilities in Land Reform and sustainable development, including the implementation of the ongoing Land Restitution, Land Redistribution of Agricultural Development (LRAD) and Settlement and now CLRA.

The success of CLRA will be largely dependent on a successful Land Rights Enquiry that will be anchored on among others, establishing the existing Community Rules and formalising them, as well as obtaining a correct Land Audit which together will form a framework for a Communal General Plan. Both spatial considerations of communal land and the participation of the community will be key to the success of the LREs. The method we are testing of a participatory mapping of land rights based on community rules verified by GPS within as GIS environment may prove an invaluable combination of tools for an effective and efficient LRE.

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ANNEX 1:

FIELDWORK: Checking variance in boundaries from first level adjudication

Method:

Donna and Denis used the digitized boundaries to identify curious boundaries that would be useful to demarcate with a GPS in order to assess variance with the demarcation community members did during the first level adjudication.

We will walk all the boundaries of parcels identified, using a GPS to record their location and detailed descriptions of both the physical markers used locally and any other physical markers that are visible.

Day One:

Parcels 84 (Nxumalo), 77, 78 and the adjacent commonage plus a triangular parcel that may be linked to 78.

Boundaries appear to follow land use and ground features. However, there are some lines that look like irregular boundaries. For instance, there is a sharp pointed boundary line separating 77 and 78. This may be following arable land and steep hills but the sharpness is curious. We know that part of Nxumalo's boundary line reflected on the maps is inaccurate because of what appears to have been a misidentification of the road the boundary follows during the first level adjudication.

It is necessary to check commonage boundaries simply because they are commonage and because the rule is that no one may settle on commonage. It would therefore be useful to know how closely local perception of the boundary on the map correlates with the actual boundary on the ground.

Day Two:

Parcel 68 (Ntuli)

Ntuli has the greatest number of ababhekiwe of any land "owner" in the area. The purpose of demarcating these boundaries with the GPS is two-fold:

- To test out a different method of obtaining these data – ie. The use of a digital aerial photograph as the base for agreeing on land rights boundaries
- To check and see whether Ntuli agrees with the umbekhwa where the boundary lies and therefore to get some indication of how disputed these boundaries may be.
- To obtain some digital data on the boundaries to begin to complete the Pilar records.

Day Three:

Parcels 64, 67 and unnumbered parcel.

There are both boundary and rightsholders disputes related to these three parcels. The purpose would be to check the variance of the map recorded boundaries to see how useful map records would be in resolving disputes. Walking these boundaries will also enable us to begin to assess the logic of features used to demarcate and whether this "logic" is at all helpful in resolving the disputes. This exercise will also test to see how open people in dispute are to engaging in physical descriptions of their parcels if we are clear that we are simply trying to record their viewpoints at this stage without attempting to resolve.
These disputes had all been solved by the time we went for fieldwork.

Day Four:

Parcels 26,27,28

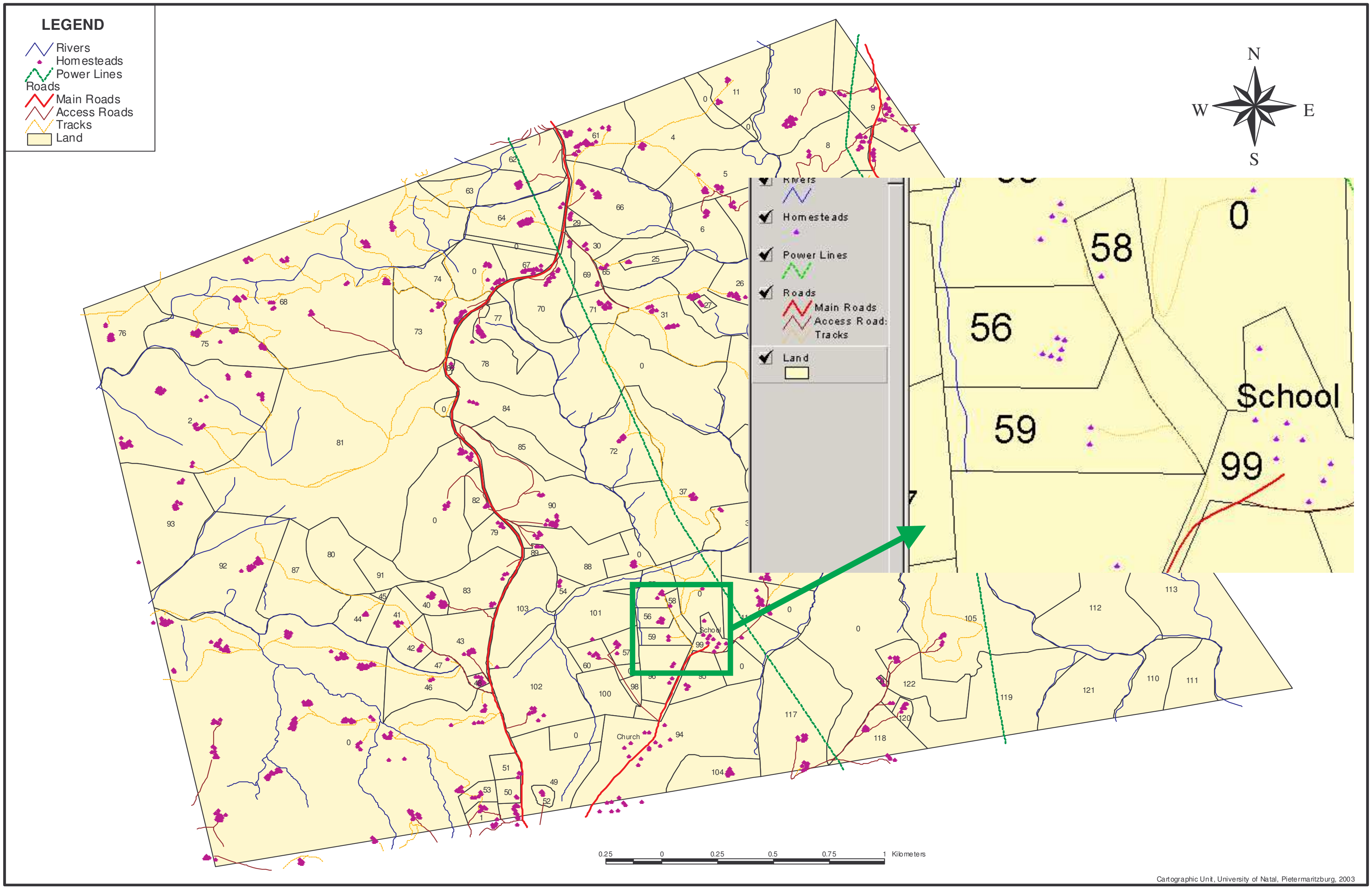
Two of these parcels have extremely straight, regular lines – a surveyor would be pleased. However, it is difficult to see how these straight lines relate to features on the ground particularly since they go through noticeable features like fields and don't necessarily follow others, like rivers. Will people be able to replicate on the ground the boundaries depicted on the maps? And if so, what are they using to locate these boundaries?

Day Five:

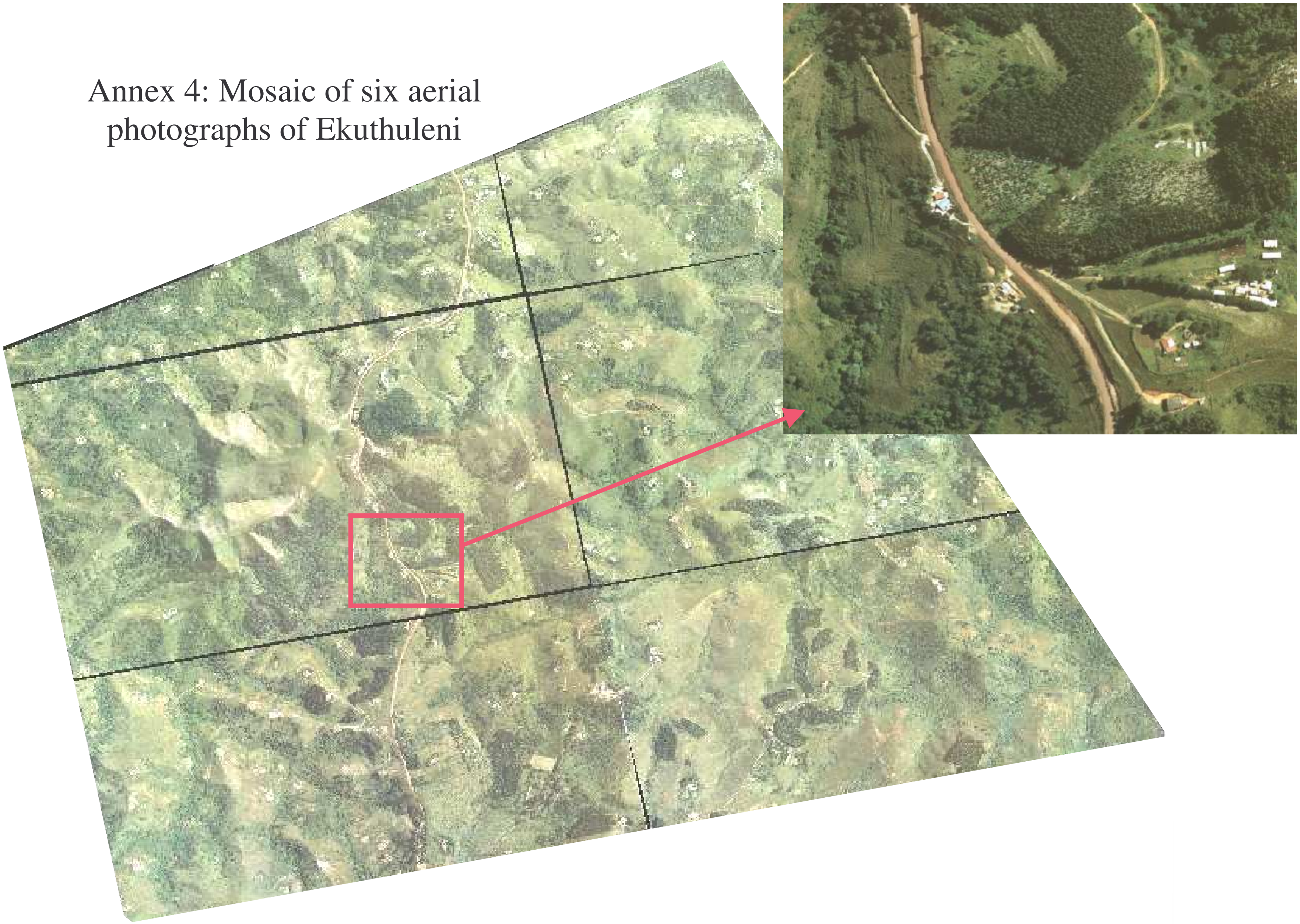
Church land

Usual variance check – maps against actual boundary on the ground. But also, find the location of the PTO boundaries and check them against the actual boundary to assess community perception against recorded evidence.

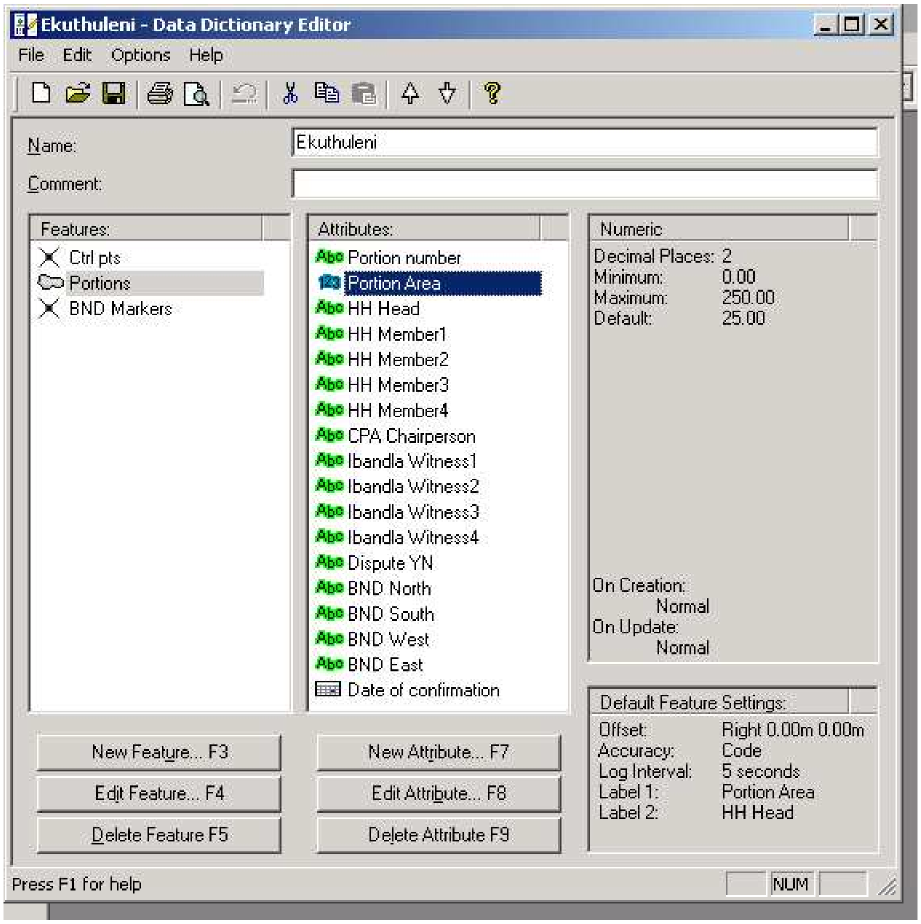
ANNEX 2: Preliminary Communal General Plan for Ekuthuleni



Annex 4: Mosaic of six aerial photographs of Ekuthuleni



ANNEX 5: Custom designed form loadable in GPS for recording descriptive information such as land right records



Land right record data dictionary (form) for recording with GPS position