Participatory Mobile Geographic Information Systems (GIS) for the Regularisation of Customary Land Administration into Statutory Law: A Case of South Africa

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Introduction

There is a new and urgent policy re-direction in Africa that seeks to support, modernise and regularise customary land administration into modern law in conformance with constitutionality and general human rights in contrast to earlier campaigns calling for replacement with statutory law adopted from colonial administration (Cotula *et al.* 2004:5-6; Republic of South Africa 2004:20). A large majority of African populations still live on unregistered communal lands administered under customary land law (Wily 2003:32; United Nations Economic Commission for Africa 2003:2). Southern African countries have developed national land policies mainly aimed at land restitution and land redistribution reform. Recent land reform policies and legislation are putting emphasis on land tenure reform that recognises customary land tenure and administration and gives equal protection to land rights whether under statutory or customary law (Wily 2003:34-38; Cotula *et al*. 2004:5-7).

Some of these countries have enacted legislation to give effect to the adopted policies. South Africa is in the final stages of preparation for the implementation of the Communal Land Rights Act of 2004 (CLaRA). One of the instruments in implementing CLaRA will be the formalisation, through the Land Rights Enquiry (LRE), of ‘community rules’ for land administration (Republic of South Africa 2004:20). The advocacy for the decentralisation of land administration by formalisation of the informal communal land administration systems have up to the enactment of CLaRA been well argued, to mention a few, in Fourie (1996), Fourie and Gysen (1995) and Leisz (1996). 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 centralised 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 a functional decentralised land administration system for the capital-poor rural residents (Wily 2003; Gartell and Hodson 1997). 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 standards by legislation. Hawerk (1997) suggested that since 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. Various other alternatives to conventional surveying as a basis for formalising communal land administration have been proposed (Fourie 1994:12-13; Fourie and Gysen 1995; Jackson 1996).

This article provides evidence-based justification for employing Participatory Mobile GIS in efforts aimed at modernising and regularising customary land administration to achieve equitable security of land tenure for all, building on various alternatives. The article presents and discusses the significance of results obtained from an area measurement exercise of a moderate size farm in South Africa and from similar studies elsewhere in the developing world using Participatory Mobile GIS methods in comparison with conventional mapping methods. An assessment of time efficiency, affordability and appropriateness of the technology is discussed in consideration of the socio-economic and legislative circumstances under consideration in the modernisation of customary land administration. The findings of this study show that Participatory Mobile GIS is time and cost efficient and appropriate and can meet legislated standards of quality. In the case of South Africa, both spatial considerations of communal land and the participation of the community will be critical to the success of the implementation of the CLaRA as an instrument for regularising customary land administration into statutory law.

Participatory Mobile GIS Alternatives to Conventional Surveying

Three alternatives to conventional surveying are proposed by Fourie (1994), Fourie and Gysen (1995) and Jackson (1996). These include the 'general boundary' method, the 'mid-point' method and the 'block, super-block' method. The 'general boundary' method is whereby local authorities subdivide land based on boundaries agreed upon by neighbours. Lower precision surveys can then be carried out without reference to beacons. This method is not viable where boundary contestations are prevalent.

The 'mid-point' method is an option whereby a single point in the centre of a property marked by a stake is registered and this could be maintained in the Surveyor General's formalised system. A combination of the general boundary method and the mid-point method using a handheld 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 as possible to roads and other infrastructure. Low accuracy GPS might not be appropriate for such residential conditions. However, higher accuracy (sub-meter) handheld GPS have recently become available and their costs are becoming more affordable for capital-poor land-managing organisations and agencies.

The 'Block and Super Blocks' method involves the accurate survey of a communal area within which lower precision and therefore cheaper subdivisions may 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 the Communal Land Rights Act of 2004 (Republic of South Africa 2004:12), suggests that the 'Block and Super Blocks' concept may be applicable in its implementation. The Act stipulates that Land Rights Enquirers will assist the communities in regularising 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 the communal 'block' of land will therefore be transferred to the Juristic Entity. The Act requires that community rules be translatable into secure rights that may be used as a basis for the Minister of Land Affairs to subdivide the 'block' into individual land rights. However, CLaRA also makes provision for individuals to convert their land rights to individual title through an application process.

Some of the outstanding key challenges facing the modernisation of customary land administration into statutory law and subsequent operationalisation include the need to develop innovative land registration methods. Wily (2003) inferred a common objective among most land reform programmes in Africa of adapting land registration systems that are simpler and cheaper and therefore able to capture as many land rights as possible into a modern management system within a reasonable length of time. In this regard, verification and adjudication processes that precede land right registrations may be undertaken by cheaper but easier to relate to trained residents as opposed to professional or government agents.

A non-conventional survey using high-accuracy handheld GPS devices may be carried out not only because they are cheaper than professional formal surveys, but also because they allow participation of witnesses and stakeholders. Modern handheld GPS devices have output screens that allow users to see progress of a mapping exercise, in case of land rights registration, to see the demarcation as it proceeds. The combination of GPS, GIS and participation of non-experts, now termed 'Participatory Mobile GIS' has become a method that is accepted as transparent in such exercises as land rights adjudication, recording and electronic transfer into an existing digital land register, information system or database.

The Participatory Mobile GIS method is aimed at achieving the following general improvements in effectiveness and efficiency of land tenure security by allowing for the following (Cotula 2007; Deichmann and Wood 2001; Fourie 2002; Lor and Onkalo 2004; Lyons and Chandra 2001):

- Community participation which guarantees transparency and therefore community confidence and quality control of adjudication and demarcation processes;
- Community participation which 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;
- 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; and
- 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.

Research by Wily (2003) shows that with the exception of South Africa, many national land reform policies prefer local level adjudicators and do not require a formal cadastral survey in order to register customary land rights. However, although South Africa requires a cadastral survey as stipulated in the Land Survey Act of 1997 to capture communal land rights (Republic of South Africa 1997a), the Act provides for such surveys to be conducted using GPS devices provided they meet stipulated accuracy standards.

This article, as indicated earlier, provides a review of previous research regarding realistic accuracy levels that can be expected from the available GPS technology for unconventional land rights surveys, the achievable time and cost efficiency, appropriateness of methods being put forward for the targeted socio-economic settings as well as simplicity of deployment of the proposed methods. Very few Cost-Benefit Analysis studies have been done on using GPS as an alternative to conventional cadastral surveying and mapping (see Barnes and Eckl 1996; Barnes *et al.* 1998; Louw 2005; Lyons and Chandra 2001; Schnurr 2004). Of these, Barnes and Eckl (1996) was the most comprehensive. They designed and carried out studies to test the performance of GPS technology under controlled conditions at 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.

Realistic Accuracy of GPS Surveys

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; and
- 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 1 metre 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 sub-metre accuracy level, certain specifications with regard to equipment, measurement tolerances, field survey and computations must be followed.

The South African Council for Professional and Technical Surveyors (PLATO) publishes a tariff of fees for its registered membership (Republic of South Africa 2003:134-143). A summary of land surveying activities that may be charged fees for the creation of Land Rights in Townships through lodgement of a General Plan can be found in PLATO tariff of fees publication which is updated as necessary. This summary seems closest in analogy to the envisaged Communal General Plan as described in CLaRA.

The cost categories of the conventional land survey method are largely similar to those of the GPS-based method. The main difference would then be in the equipment used and which in turn is dictated by the accuracy level demand. The conventional method also does not need capitalisation, as Land Surveyors should already be well equipped and adequately trained. The PLATO guidelines also include a cost category ‘Additional work’ which mainly entails the surveying and mapping of servitudes, curvilinear boundaries and outer boundaries that constitute a General Plan. In the GPS-based method, this categorisation 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 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 Electronic Distance Measurement (EDM) device in conventional surveys. As GPS-based method is built on cost-effectiveness, the methodology designed includes hand-held units. Therefore, 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.

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 1 metre (Lyons & Chandra 2001; Schnurr 2004):

- 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 0.25 m spatial resolution of the aerial photograph indicates that objects as small as 25 cm 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 a 'Carrier Smoothed Differential Code' GPS. The 0.5 m spatial resolution of the base photograph means that objects as small as 50 cm 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 relatively expensive.

The third method that can produce a final map at an accuracy level of less than 1 m is the use of the IKONOS™ satellite imagery as base data. The image has a spatial resolution of 1 m, which is still good enough for participatory interpretation and mapping. However, the imagery is relatively expensive (at around US$3,000 a scene using 2006 prices) for the envisaged purpose. It should, however, be noted that the acquisition of the satellite imagery costs as 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 time and cost efficiency of the conventional land survey method against the GPS-based method. Although the three studies did not employ the same GPS equipment, results obtained reported consistency in productivity and efficiency. The comparison in terms of productivity rates in Albania (Barnes and Eckl 1996) found the GPS-based method was twice as productive in the field and 7-8 times more productive in the office. Lyons and Chandra (2001) reported the Conventional method to be 2.5 times more costly than the GPS-based method in Asian countries while Louw (2005) found the Conventional method to be 3 times more costly in Namibia than the GPS method.

Appropriateness of Participatory Mobile GIS Surveys

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). 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, in 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 sub-metre accuracy currently costs about R30,000 based on 2007 prices.

Simplicity of 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 with it being 8 times faster than the conventional method, as mentioned earlier.

Study Methodology

One of the objectives of this research was to develop and test a Participatory Mobile GIS methodology for identifying and mapping communal land administration boundaries. The method involves active participation by the locals, the natural owners of the land to be mapped. Maps produced through the established methodology should meet the desired high precision standards of survey. The Ukulinga case study was embarked on in an effort to develop a better understanding of the principles and operation of high precision handheld GPS and to establish their accuracy levels attained in surveys as well as applying the participatory mapping approach.

The Ukulinga University Research farm (farm no. 14068) is located south of Pietermaritzburg city, KwaZulu-Natal Province, South Africa. The farm is approximately centred at latitude -29.67ºand longitude 30.41º and has an irregular pentagonal shape tilted along the north-west to south-east axis. High barbed and razor wire fencing, most of which is electrified, marks the farm boundary to the north, east and west, while the southern boundary is marked by a stream that runs west-east contributing to the Mkondeni stream which itself is a tributary of the Msunduzi river.

A copy of the 1953 Ukulinga farm survey diagram was obtained from the Surveyor General's office in Pietermaritzburg and used as a reference in the GPS-based participatory mapping exercise and accuracy assessment. The Ukulinga farm manager, acting in his capacity as the proxy owner of the property, participated in the mapping process thereby providing local expert knowledge and pointing out the farm boundaries. The GPS coordinate points of boundary markers were then corrected by differential GPS post-processing. The stream boundary was visited to cross-validate it with the survey diagram and cadastral map.

The 1953 survey diagram, a digital panchromatic ortho-rectified aerial photograph (Spatial resolution 0.75 m), a digital 1:50,000 topographic map of the area (topo-sheet g2930cb) as well as a vector map of the cadastral boundaries were used as references in locating the farm and in identifying farm boundaries. The survey, as undertaken by this study, recorded new farm boundary markers as the original farm boundary beacons could not be found. An assessment of relative accuracy was carried out by comparing the farm area as calculated using the Participatory GPS-based Mapping method with the same area as in the 1953 survey diagram and in the cadastral map.

The mainly 'rail' steel corner post boundary marker points were captured by GPS from 30th October to 1st November 2006. The survey diagram obtained from the Surveyor General showing original positions of survey beacons was used as a guide in capturing boundary marker points by GPS, which were then used in reconstructing the boundary and in calculating the area of the farm for accuracy comparison. However, none of the original beacons were recognised as described in the survey diagram prepared in 1953. The Ukulinga farm extent has been substantially expanded since the 1953 land survey and understandably, the operational farm fencing including security considerations seem to have taken priority over the preservation of the original farm boundary beacons.

Boundary markers points in the form of fence corner steel posts as pointed out by the farm manager were identified along the original boundary and used to reconstruct the new farm boundary. It was therefore not possible to make accuracy comparisons of the survey diagram beacons coordinates with GPS measured ones. As mentioned in the survey methodology earlier, comparison was only possible once the GPS captured boundary marker coordinates had been differentially corrected and used in reconstructing the farm boundary through on-screen digitising using the ortho-rectified aerial photograph as a backdrop reference image in a GIS.

Moreover, while surveying the Ukulinga farm boundary, a trigonometric beacon was found just outside the property, but along the fence marking the northern boundary. The trigonometric beacon is labelled BI – EY 230 with altitude 832.8 metres above sea level, latitude 29°39′46.2496″S and longitude 30°23′56.7300″E. The opportunity was taken of a GPS recording of the trigonometric beacon coordinates as well as altitude and to compare them with those precisely measured by the Surveyor General.

Accuracy of Differential GPS Point Measurement

Comparison of coordinates and height of the trigonometric beacon as measured by the Surveyor General with those captured by the GPS showed a difference of 3.2 m in elevation representing a vertical error of 0.38% and a displacement representing a horizontal error of 0.002 m. The calculated relative accuracy is based on the assumption that the position and height of trigonometric beacon as determined by the Surveyor General's office are of a high accuracy and the GPS measurement error as being a magnitude of deviation from these values. The 0.2 mm horizontal error obtained by the GPS measurement was therefore well within the tolerance levels set by the Survey Regulations (Republic of South Africa 1997b).

Accuracy of Measured Area Using Participatory Mobile GPS

As mentioned previously, no survey beacons as described in the original survey diagram could be recognised and new boundary markers had to be captured using GPS choosing corner posts of boundary fencing as proxy survey beacons. Accuracy assessment could, therefore, only be carried out by comparing areas of the reconstructed farm boundary and the farm area as recorded in the survey diagram and as attributed in the cadastral map. The comparison of the areas revealed a difference of 0.2409 ha representing a 0.12% overestimate error between the GPS derived area and the area recorded in the survey diagram. A difference of 0.1794 ha represented a 0.09% overestimate error within the cadastral area. These accuracy levels are corroborated by the Irrigation Training and Research Centre (Irrigation Training and Research Centre 1998) as being within the expected accuracy levels for the method used.

Conclusion

This study has shown that Participatory Mobile GIS allows cheaper and simpler spatial description of land rights irrespective of whether locally-based land adjudicators or professional cadastral surveyors are deployed, or whether the land right is to be entered in a centralised system or a decentralised system. Moreover, most African countries are indicating a preference for locally-based adjudicators of good standing in their community, as this is seen to promote transparency. The Mobile GIS technology made up of hand held devices allows participation of available stakeholders on the land itself and therefore allows quality assurance by stakeholders as witnesses in the adjudication and recording processes.

A number of methodological as well as tools and skills issues should be noted prior to consideration of deployment of the method tested in this study. Rectified, ortho-rectified (ortho-photos) as well as unrectified aerial photographs at various scales, in colour or panchromatic have been used beneficially as tools for participatory mapping 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.

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 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.

It should also be noted that even the high accuracy GPS will lose the satellite signals in a deep v-shaped valley. This emphasises the appropriateness of using GPS in combination with aerial photographs or high resolution satellite imagery. Technology has now allowed maps produced by rural communities in participatory mapping processes to be geo-referenced and to be integrated with other spatial data, thereby enhancing the quality and quantity of information derived. Participatory mapping exercises are increasingly done against a rectified background aerial photograph or satellite image 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 as well as Land Redistribution and Agricultural Development (LRAD) programmes and in modernising customary land administration into statutory status through the implementation of CLaRA.

Successful implementation of CLaRA will be largely dependent on a successful Land Rights Enquiry (LRE) that will be anchored on among others, establishing the existing community rules and their subsequent formalisation, as well as obtaining adjudicated land audits 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 critical to the success of the LREs and to the overall success of regularising customary land administration into statutory law.

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