ANALYSIS AND MAPPING OF BASIC COMMUNAL LAND ADMINISTRATION SYSTEMS USING PARTICIPATORY GPS AND GIS: A CASE STUDY OF MAKURUNG VILLAGE

by

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ABSTRACT

Participatory GPS and GIS mapping is a mapping process that involves active participation of the local communities with the assistance of outsiders who are experts in the field. The objective of Participatory GPS and GIS mapping is to produce a technically accurate and socially acceptable participatory map and to facilitate skills transfer to the participant community.

A basic communal land administration system is a land administration structure responsible for the administration of a local, elementary area of jurisdiction (a village) occupied by a tribe whose rights to land are derived from shared rules determining access and is normally led by an Induna. The analysis of such a structure could provide a foundation for the implementation of Communal Land Rights Act, 2004 (Act No 11 of 2004) that is, the transfer of communal lands to communities.

A sub-metre accuracy is obtainable after post-processing differential correction as acclaimed by Trimble on the Geo-XT™ GPS unit and proven in the Ukulinga case study.

Participatory GPS and GIS mapping guarantees effective and efficient skills transfer to participant communities and accurate recording of boundary data. Maps produced through Participatory GPS and GIS mapping are widely acceptable since they are preceded by discussions and subsequent consensus on boundary data points prior to actual recording, thereof.

The study was designed to analyze basic communal land administration systems and to develop a methodology for mapping them. A successful implementation of the Communal Land Rights Act, 2004 required spatial and related information on land administration structures. A Participatory mapping methodology designed was tested in two case studies and found to be reasonably accurate.

DISCLAIMER

This mini-dissertation represents the original work of the author and has not been submitted in any form for any degree or for any other purpose at any university or institution of higher learning. Where use has been made of work by other authors, it is duly acknowledged in the text.

M.M. MALEKA

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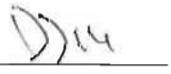

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ABBREVIATIONS

BTA – Bakgaga Traditional Authority

CLaRA – Communal Land Rights Act, 2004 (Act No.11 of 2004)

GIS – Geographical Information System

GPS – Global Positioning System

IPILRA – Interim Protection of Informal Land Rights Act, 1996 (Act No.31 of 1996)

Interim Procedures – Interim Procedures Governing Land Development Decisions which Require the Consent of the Minister of Land Affairs as Nominal Owner of the Land

PTO – Permission to Occupy

GLOSSARY

Induna is a traditional leader who is under the authority of, or exercises authority within the area of jurisdiction of, a Chief or Chieftainess in accordance with customary law.

Chief is a traditional leader under whose authority or within whose area of jurisdiction an Induna exercises authority in accordance with customary law.

Chieftainess is a female counterpart of Chief.

Kgoshigadi a Sepedi word for the Chieftainess.

Geographical Information Systems (GIS), Hastings (2005), represent a class of software systems used with spatially distributed data and organised around similar geographical data-object and attribute structures.

Land tenure is the nature and range of rights that individuals have to land, water and other natural resources in relation to rights exercised by individuals, groups and the state (Torhonen 2003).

Customary land is land held in accordance with customary law (Rusanen 2005).

Customary tenure is land held under customary laws, and governed by traditional rules and regulations (Obala and Kinyungu 2005).

Global Positioning System (GPS) is a worldwide radio-navigation system formed from constellation of 24 satellites and their ground stations (http://www.trible.com/gps/what.html).

Royal family means the core customary institution or structure consisting of immediate relatives of the ruling family within a traditional community. (Traditional Leadership and Governance Framework Act, 2003 (Act 41 of 2003)).

Senior Mokgomana is the Chief or Chieftainess' assistant.

Bakgomana are the Chief or Chieftainess appointed councilors who assist in the administration of the tribal authority.

Mokgomana refers to singularity of the term Bakgomana.

Senior Mokgomana is the Sepedi phrase for Chief Induna.

Kgoro is a tribal or community meeting called by the Chief or Chieftainess or Induna where wide range of issues of interest to the tribe is discussed.

1. BACKGROUND

1.1. Introduction

The Communal Land Rights Act, 2004 (Act No.11 of 2004) (CLaRA) presents to indigenous communities both the challenge and opportunity to map their communal land administration boundaries. Traditional survey(s) which require(s) technical knowledge to undertake, more time to accomplish and costly to commission are being rejected in favour of modern GPS and GIS operations. Currently there is movement towards participatory mapping; benefits thereof overwhelming the disadvantages.

It is the objective of this study to analyze basic Communal Land Administration Systems, and develop a participatory GPS-based methodology that could form a foundation for identifying and mapping communal land administration boundaries. Analysis of basic Communal Land Administration Systems is crucial to take stock of the available structures and their functioning to support the implementation phase of CLaRA. The South African government intends to transfer communal land in ownership to communities. It therefore becomes necessary to develop a user-friendly model that would assist communities to identify and map the boundaries of their communal lands.

Through this study an analysis of a Basic Communal Land Administration System and a Participatory GPS-based methodology for mapping communal land administration boundaries is presented.

1.2. Problem Statement

From time immemorial, indigenous people stayed together in communes with each household enjoying exclusive rights to designated areas while enjoying common usufruct rights to other portions of land such as the pastures, woodlots and water sources/points. Indigenous people were governed by traditional leaders through customary law (Marongwe, 2003). Colonial conquest of the indigenous people gave rise to major disruptions of the administrative practices of the indigenous people. Repressive laws were introduced to undermine, humiliate and dehumanize indigenous people.

The Black Administration Act, 1927 (Act No. 38 of 1927), the Development Trust and Land Act, 1936 (Act No. 18 of 1936), the Black Authorities Act, 1951 (Act No. 68 of 1951) and the Black Areas Land Regulations, 1969 (R188 of 1969) modified the substance and content of the role of traditional leaders and institutions in land administration (Sibanda, 2006). The indigenous customary systems of land administration were changed to suit the needs and interests of the colonial political economy.

The Communal Land Rights Act, 2004 (Act No.11 of 2004) (CLaRA) intends to transfer communal land to communities and to establish democratic land administration structures to administer communal land. It is necessary to take stock of existing land administration structures and understand how they function. Insight into existing structures informs the way forward.

This study analyses and develops tools for mapping basic Communal Land Administration Systems using Participatory GPS and GIS. Prior to mapping communal land the extent of the communal area has to be defined by the community. The study presents a generic process to follow in obtaining information from the community defining the boundaries of their land area and presents the output in the form of community developed map.

1.3. Research Objectives

- To analyze basic Communal Land Administration Systems.
- To develop a participatory GPS-based methodology for identifying and mapping communal land administration boundaries.

1.4. Research Questions

The following research questions are pursued in this study:

- What land allocation and administration structures and systems exist in communal areas?
- How are boundaries of a basic communal land administration defined?

2. LITERATURE REVIEW

LAND ADMINISTRATION SYSTEMS

2.1. Background to Communal Land Administration in Africa

Land Administration in Africa, Augustinus (2003), consists of the conventional land administration systems based on land registration and; customary and/or informal land administration systems. The majority of African countries' populations use the customary land administration system, especially in rural areas. Colonial land administration laws remain entrenched in many African countries today (Augustinus, 2003). The predominant tenure systems in Southern Africa (Marongwe, 2003) are private/freehold property, state property, communal property and the open access property.

In a comparative study of five countries in Africa, Augustinus (2003) presents a Table representing formal and customary coverage below:

Title and customary	Uganda	Namibia	Mozambique	Ghana	South Africa
Customary coverage	62% of surface but about 68% of population	Majority of population	90% of transactions	78% of total area	10% of area but about 25-30% of rural former homeland population
Title /deed coverage	12-15%	Majority of surface area but not majority of population	1-15%	Unknown	80-90% of area but excludes at least 25-30% of population
No. of registered titles/deeds	700,000 titles	Unknown	Unknown	11,383 titles/deeds unknown	6,996,658 deeds

Table 1. Formal and Customary Coverage of five African Countries. Source: Augustinus (2003)

Before colonialism took root in Southern Africa and Namibia, indigenous tribes occupied and ruled the territory according to then prevailing customary tenure practices. Communal land granted land use rights to occupation of land in perpetuity. The land tenure systems in Africa were almost universal and primarily based on communal use (Iivula-Ithana, 2001). Land belonged to the community and was held in trust by leaders of respective communities. In Zambia, Marongwe (2003), customary land occupies about 96.5% of the country and traditional chiefs and their village headmen administer this land. The 1995-land law in Zambia has permitted the issuing of freehold title in customary land (Marongwe, 2003).

According to Malawi National Land Policy (2000) land rights derived from the traditional system of land tenure are reducible to the ownership of specific rights by individuals, families and communities. Provision will be made to rationalize and accord full statutory recognition to customary land rights. In South Africa, the Communal Land Rights Act, 2004 recognizes customary land rights and provide for the transfer of such rights to communities.

Chiefs rely on clan and family leaders to identify and actually allocate pieces of land to individuals and households from land owned by that group. Once allocated, the family land is held and managed in all respects as private property (Malawi National Land Policy, 2000). Generally, once an individual had been allocated a parcel of land, ownership was perpetual through cultivation (including fallow periods) and could be inherited upon the death of the owner (Marongwe, 2003). This practice is common to most African countries.

According to Anderson (2000), the national government of Mozambique continues to own all the land, but grants land-use rights to individuals and entities after consultation with communities in the area, documented in *Lei de Terras* (1997 Land Law) and *Companha Terra* (a 1998 public awareness campaign). Any person who has occupied land for ten years or more, without any needed paperwork, automatically has rights to continue to use that land.

The challenges facing land use and land tenure issues in Africa, Crosnier (2000), are being exacerbated by competition for natural resources, increasing demand for croplands and the fast pace of development. Factors such as a co-existence of private land ownership structures inherited from the colonial era, Islamic law and local customs, give rise to a complex situation involving issues that trigger conflicts (Crosnier, 2000).

Augustinus (2003) identifies, amongst others, the following characteristics as some of those that affect land administration in Africa:

- Customary tenure is often secure and titling is unnecessary.
- Land markets are not free. Sale is limited to relatives (by blood and/or marriage), and/or ethnic/national groups, and/or religion in certain areas and/or to men and occurs outside the formal titling system.
- Women's rights to land are often nested in that of the family.

Crosnier (2000) identifies the following characteristics that apply to land use and land tenure issues in most African Countries:

- A land record system inherited from the colonial period applicable to a limited number of parcels, mostly in urban areas;
- A land allocation system that allows people to use communal lands without granting them ownership rights;
- Unregistered lands, which make most of the country, belong to the State;
- Communal lands are allocated by local chiefs with ancestral powers.

It is clear from the above deliberations that customary land constitutes a major part of land in most African countries. The better part of this land is not registered and is largely owned by the government. In the light of current moves by governments to recognise the occupants of such land as owners, including South Africa, this study offers an efficient and effective participatory GPS and GIS mapping

methodology that could assist in securing tenure rights of the occupying communities.

2.2. Communal Land Administration Systems in South Africa

Two distinct types of communal land exist in South Africa, namely state-owned communal land and privately-owned communal land (Department of Land Affairs, 1998). State-owned communal land refers to communal land registered in the name of the state but administered by a tribal authority. This type of communal land is further categorised into three, namely; land occupied by (but not allocated to) tribes, land held in trust for tribes by the Minister (bought farms) and land allocated to tribes as per relevant proclamation. Customary tenure system applies to the state-owned category of communal land. Land holding is governed by rules and regulations of the community or tribe and ownership of the property is communal (Department of Land Affairs, 1998). Although the community is clear as to where exclusive usage rights occurs and where communal access is applicable such rights are mostly not documented. The rights are less secured as they could be withdrawn by governments through proclamations (gazettes) or be a subject of conflicts emanating from overlapping land rights (Department of Land Affairs, 1997). The land some tribes occupy was allocated as a reward for collaboration with the apartheid regime or dispossession as punishment to the real tribes who had underlying historical rights based on indigenous title (Claasens, 2001).

Privately-owned communal land is communal land acquired through either of the two land reform programmes, namely redistribution and restitution of land rights. It is administered by a juristic persona in the form of Communal Property Association (CPA) or Trust. Members of the CPA or Trust are registered against the title deed of the acquired property. Only the head of household, not the entire family membership, get registered on the legal entity. The legal entity will have a freehold title to the land whereas the community members will enjoy communal ownership unless otherwise provided for in the constitution of the legal entity.

2.3. Legislative framework

As discussed under the problem statement, the colonial government in South Africa enacted a number of legislation to entrench its rule over the indigenous people. This legislation modified the substance and content of the role of traditional leaders and institutions in land administration, (Sibanda, 2006).

The advent of democracy in 1994 underpinned by the commencement of the Constitution of the Republic of South Africa, 1993 (Act No. 200 of 1993) (Interim Constitution) ushered a new beginning for land administration in South Africa. The constitution became the primary source of all law in South Africa (Van Wyk, 1999). Laws, including land administration laws, had to be in harmony with the constitution. Those laws found conflicting with the constitution were to be repealed or amended to accord with the supreme law. Racially discriminatory laws, such as the ones alluded to earlier, were either repealed or are in the process of being repealed.

Laws such as the Interim Protection of Informal Land Rights Act, 1996 (Act No. 31 of 1996) (IPILRA) were promulgation to address the vacuum thus created by the repeal of certain laws. Subsequent to the enactment of IPILRA, the Interim Procedures Governing Land Development Decisions, which require the consent of the Minister of Land Affairs as nominal Owner of the land (Interim Procedures), were developed to provide policy guidelines towards the implementation of the Act. IPILRA and Interim Procedures restored the lost dignity and citizenship eroded by colonial legislation to the indigenous majority.

The White Paper on South African Land Policy (1997) provided policy direction with regard to, among other policy issues, the administration of communal land. It acknowledged that people had stayed on land for a very long time and some of whom had purchased land but did not get title deeds. It is in the spirit of the policy document that the rights of the long term holders of the land should be treated as

ownership rights. *"No tier of government should treat the land as state owned"* (White Paper on South African Land Policy, 1997 (p.63)). The policy document criminalises acts by anybody, including a tier of government, which undermines the rights holders of such land by not consulting them in all matters that affect their land rights. *"Rights holders must be consulted in all matters pertaining to their land rights. Anything less would amount to confiscation of historical or indigenous land rights"* (White Paper on South African Land Policy, 1997 (p.63)).

The Communal Land Rights Act, 2004 (Act No. 11 of 2004) (CLaRA) due for implementation soon, will formally recognise land ownership by the indigenous communities since it intends to transfer in title land occupied by such communities, after a land rights enquiry process meant to ascertain rights-holding of such lands, to rightful owners and to compensate comparably those land rights-holders whose land rights could not be restored. An effective and efficient participatory GIS and GPS mapping methodology is required to guide the land rights enquiry process.

2.4. The Role of Communal Land Rights Act, 2004 (Act 11 of 2004) in Communal Land Administration

The Communal Land Rights Act, 2004 (Act No. 11 of 2004) will transform communal land administration to meet the current and future development challenges facing communal areas. The objective of the Act is to, among others, provide for legal security of tenure by transferring communal land, including KwaZulu-Natal Ingonyama land, to communities, or by awarding comparable redress where such transfer is not possible. The Act provides for the democratic administration of communal land by communities through the establishment of Land Rights Boards at provincial level (Section 25 of Act No.11 of 2004). At community level Land Administration Committees will be established to administer land affairs of that particular community (Section 21 of Act No.11 of 2004). A community should develop its rules that will govern its land administration and have them adopted as per provisions of Section 19 of Act No.11 of 2004. The

process of developing community rules is expected to be participatory and inclusive of all affected parties. Land Administration Committees will replace the current tribal authorities as land administrators. The expected impact of the implementation of Communal Land Rights Act, 2004 is the development of a democratic, people-centred, transparent and participatory system of land administration.

2.5. The Need for Mapping Communal Land Administration Systems

The Communal Land Rights Act, 2004 (CLaRA) advocates the transfer of communal land to its rightful owners. Repressive governments dispossessed indigenous people of their land rights through acts of parliament (Land Acts 1913 and 1936, proclamations, etc.). Section 15, 16 and 17 of Act No.11 of 2004 provides for the designation or appointment of a Land Rights Enquirer, his or her notice and powers and duties thereof. A Land Rights Enquirer will investigate land rights that a particular community claim to have on a specific portion of land for whose transfer an application is made. The enquiry will assist the Minister in making a determination as per Section 18 of Act No.11 of 2004. It is a requirement that the boundaries of the affected portion of land be delineated so as to map the land due for transfer to the community. Most of the land affected by CLaRA, 2004 was not surveyed. Even on the surveyed land overlapping land rights are likely to emerge. Professional survey is expensive to carry out and time consuming. Judging from the current demand for transfer of land and limitation of resources, a more effective and efficient participatory land rights mapping methodology is required to support speedy transfer of land to communities.

In Indonesia, community mapping has been directed towards providing evidence of ancestral use of land that have been incorporated into protected areas, (Poole, 2003). Community-based mapping in Malaysia, Poole (2003) has been about defending community lands that are already recognized, but not accurately mapped.

In South Africa, indigenous lands are mapped to strengthen land rights holders' security of land tenure. Mapping of communal lands is an integral part of the land rights enquiry process that would serve to secure land rights that are, under current circumstances, insecure. The land rights enquiry process is represented by Figure 1, step four (4), (spatial data model for generic CLaRA implementation cycle).

Spatial data output Generic project cycle steps Spatial data requirements

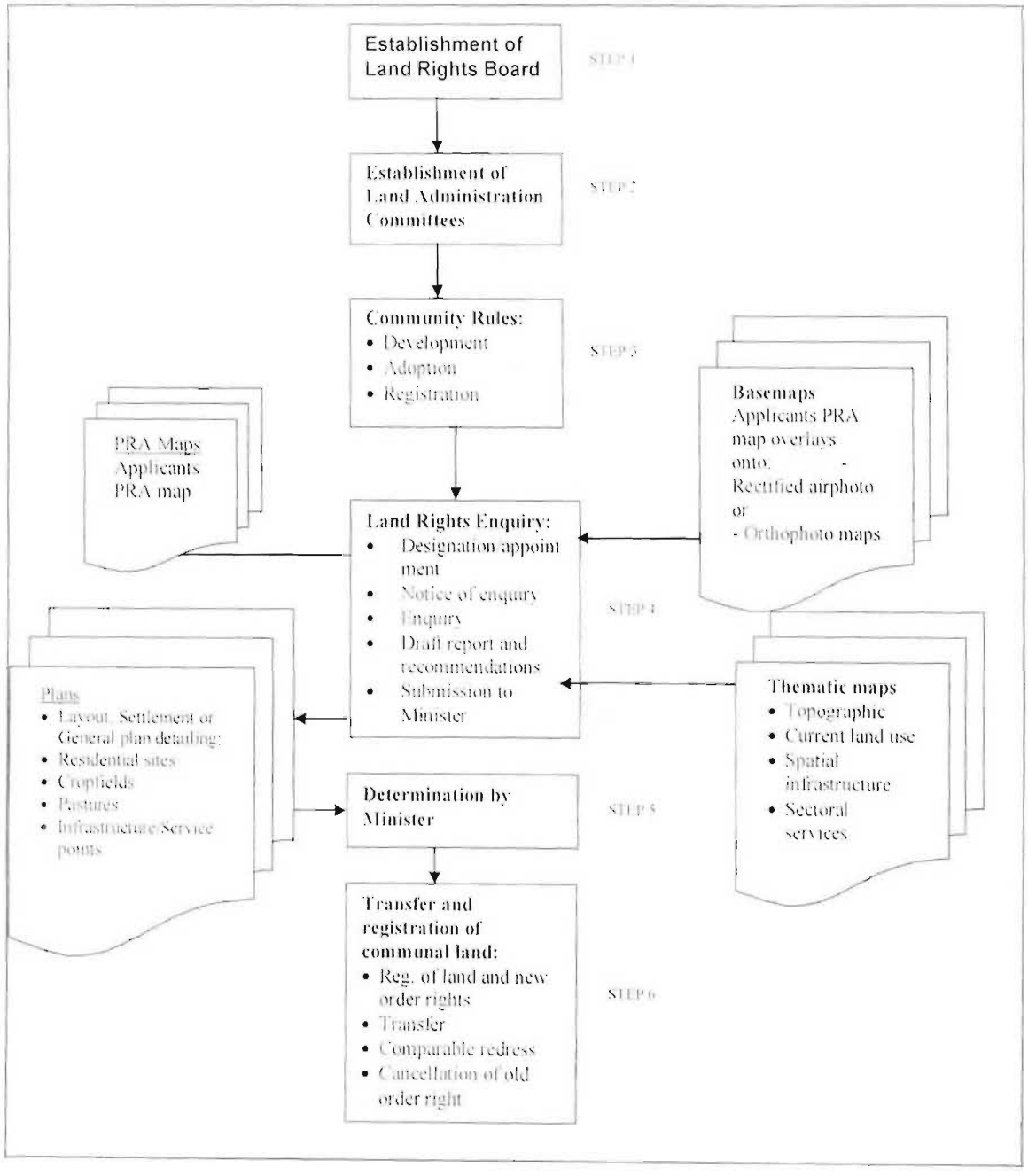


Figure 1: Perceived Spatial Data Model for a Generic CLaRA Implementation Cycle

2.6. Description of Existing Communal Land Administration Structures

Communal land is largely administered by traditional authorities in traditional communities and by elected civic representatives in non-traditional communities or where the system of traditional leadership has collapsed. In larger African Traditional Communities the Paramount King is the highest authority, presiding over a number of Chiefs, under whose jurisdiction are Indunas as direct subordinates (personal experience). The Induna provides leadership at the basic (elementary) administration level to ordinary members of the community who are subjects of the Chiefs and the King. In smaller African Traditional Communities the Chief is the supreme leader over the Indunas and the general tribes-people.

None of the three centres of power act solitarily. There are tribal land administration structures attached to each centre of power. The Paramount King has a land administration structure that is constituted by members of the royal kraal, Chiefs and Advisers drawn from the philosophers who are often the most enlightened members of the community and Administrators.

The land administration structure under the leadership of a Chief or Chieftainess is generally constituted by the members of the royal family, Chief or Chieftainess appointed Bakgomana, Indunas, Administrators, Advisers and the Community appointed Tribal Councillors.

At the basic land administration system of Induna-level the structure is made up of members of the Induna's immediate family, administrators and advisers. The consultative nature of communal land administration requires the King, the Chief or Chieftainess and the Indunas to consult with their structures on all administrative matters. They, however, reserve the right to make final decisions.

2.7. Challenges Associated with the System of Communal Land Administration

The system of communal land administration has to come to grips with numerous challenges. For the system to prevail, it has to find strategies to deal with these challenges and overcome them. Problems that have characterised the efficient, effective and sustainable operation of the land administration systems on communal land are many. Sibanda (2006) identifies four major causes:

- The confusion emanating from an overabundance of legislation, regulations, proclamations and administrative regimes dealing with land administration systems and other land related matters in these areas.
- The invalidity of PTOs issued by various persons, institutions and structures since 1994, except for KwaZulu-Natal province.
- The development and operation of informal systems of land administration in communal areas caused by the disintegration of the land administration systems on communal land since the 27th April 1994.
- Decline in stability that effectively undermines the peoples' capacity to develop and use land in a manner that will enhance their standards of living.

PARTICIPATORY GLOBAL POSITIONING SYSTEM (GPS) AND GEOGRAPHIC INFORMATION SYSTEM (GIS)

2.8. Scientific and Technical Principles of Global Positioning System (GPS)

Global Positioning System (GPS) has three parts namely; the space segment (consisting of a constellation of 24 satellites orbiting the earth at 11 000 nautical miles), the user segment (consisting of handheld or mounted receivers) and the control segment (consisting of ground stations that ensure proper functioning of the satellites) (GPS Primer, 2003; Lange, 1996; Chivers, 2003).

Each GPS satellite takes 12 hours to orbit the Earth. A satellite transmits signals that are synchronized with those from other satellites to the ground at the speed of light. The receiver calculates the distance to the satellite by taking the difference between the time when the signal is received and the time when it was sent, multiplying it by the speed of light. To calculate its precise latitude, longitude and altitude, the receiver measures distance to four separate GPS satellites (Lange, 1996; GPS Primer, 2003).

Receivers are capable of detecting satellite signals, decoding information thus obtained and processing the satellite signals information. Although the GPS system is designed to be as nearly accurate as possible, there are several sources of errors that could cause a deviation of approximately 100 metres on average from actual position (http://www.cmtinc.com/gpsbook/chap7.html).

2.8.1. Sources of GPS Error

a) Satellite Geometry

Satellite geometry has an influence over the accuracy of the position determination. Satellites positioned close to each other from the view of the receiver leads to a "bad" geometry. A position determination may not be possible in such a situation. Should a position determination be possible, the error of the positions may be up to 150 metres (Wobner, 2005).

Geometric Dilution of Precision (GDOP) is, according to US Army Corps of Engineers (2003) the geometric effect of the spatial relationship of the satellites relative to the user. It is computed from the geometric relationships between the receiver position and the positions of the satellites the receiver is using for navigation. Wobner (2005) argues that if the four satellites viewed by the receiver are well distributed or the angle between the satellites is greater, their geometry is good and a better measurement is attainable.

According to Wobner (2005); Wormley (2005), GDOP has four components, namely; Position Dilution of Precision (PDOP) which measures the x, y and z (3D) position accuracy, Horizontal Dilution of Precision (HDOP) measures the horizontal accuracy (latitude and longitude), Vertical Dilution of Precision (VDOP) measures vertical accuracy (altitude) and Time Dilution of Precision (TDOP) that measures time accuracy. Although each of these GDOP terms can be computed individually, they are formed from covariances and so are not independent of each other.

Dilution of Precision (DOP) values, according to Wobner (2005); (http://www.cmtinc.com/gpsbook/chap7), are commonly used to indicate the quality of the geometry of the satellite constellation. Low HDOP values of less than 4 are good and are attained when the satellites are evenly distributed close to the horizon. GDOP values of 5 and greater are necessary for an accurate position determination (Wobner, 2005). PDOP values are best if one satellite is positioned vertically above and three are evenly distributed close to the horizon.

b) Ionosphere

The ionosphere is a layer of the atmosphere ranging in altitude from 50 to 500 km that consists of largely ionized particles capable of exerting a perturbing effect on GPS signals (http://www.trimble.com/gps/index.shtml). The electrons and ions are concentrated in four conductive layers that refract the electromagnetic waves from the satellites, resulting in an elongated runtime of the signals. The error induced by this layer is estimated at approximately 5 metres (Wobner, 2005).

The error effect of the ionospheric refraction produces minimal impact at night than at daytime. According to US Army Corps of Engineers (2003) the delay can vary from 40 – 60 metres during the day and 6 – 12 metres at night. The US Army Corps of Engineers (2003) further argues that GPS operations conducted during periods of high sunspot activity or with satellites near the horizon produce range results with the most error.

Electromagnetic waves are slowed down inversely proportional to the square of their frequency while passing the ionosphere. Electromagnetic waves with low frequencies are slowed down more than electromagnetic waves with higher frequencies (Wobner, 2005).

c) Troposphere

The troposphere is the lower part of the earth's atmosphere, encompassing our weather, full of water vapour and varying temperature and pressure (http://www.trimble.com/gps/index.shtml). This layer elongates the runtime of electromagnetic waves by refraction thereby causing delays in the GPS signals to the receiver (Wobner, 2005).

The refraction, according to US Army Corps of Engineers (2003) is due to moisture in the lower atmosphere.

d) Multipath Errors

According to Wormley (2005) multipath is the error caused by reflected signals entering the front end of the receiver, thereby masking the real correlation peak. The multipath error affects positioning and, according to US Army Corps of Engineers (2003) occurs when the signal arrives at the receiver from more than one path (i.e. direct signal and several bounced signals). The multipath effects are more pronounced in a static receiver near large reflecting surfaces. Error induced by the effect is approximately 1 metre.

e) Ephemeris Errors

According to US Army Corps of Engineers (2003) satellite ephemeris errors are errors in the prediction of a satellite position, which may then be transmitted to the user in the satellite data message. Slight changes in the orbit of a satellite, argues Wobner

(2005) are possible due to gravitational forces, resulting in orbital position errors. These ephemeris errors, asserts Wormley (2005) result when the GPS message does not transmit the correct satellite location. These drifts are not rapid but occur over days, thus making correction of this problem fairly simple. More accurate satellite orbit data, according to US Army Corps of Engineers (2003) can be obtained at later periods for post-processing.

f) Clock Errors

Clocks onboard the satellites are extremely accurate but do suffer from some clock drift. Such drifts may add up to 2 metres of inaccuracy (http://en.wikipedia.org/wiki/Global_Positioning_System).

2.8.2. Methods of Improving Accuracy

a) Correcting Ionospheric Errors

According to Wormley (2005) Ionospheric errors could be corrected by using dual-frequency P-code receivers to measure the signal at both frequencies and directly solve for the delay as the difference between the two frequencies' arrival time would allow a direct algebraic solution.

Ionospheric errors could also be corrected by comparing the GPS-measured position to a known surveyed location by sending a radio or other links to allow L1 only receivers to make ionospheric corrections or via satellite in Satellite Based Augmentation Systems, which transmits ionospheric data on the GPS frequency using a special pseudo-random number (PRN) (http://en.wikipedia.org/wiki/Global_Positioning_System).

b) Correcting Tropospheric Errors

Wobner (2005) asserts that the tropospheric error could not be eliminated by calculation, although smaller than that of ionosphere. However, he argues, could only be approximated by a general calculation model.

Through the implementation of Wide Area Augmentation System (WAAS) and Europe's Geostationary Navigation Overlay Service (EGNOS), Wobner (2005) asserts, "maps" of the atmospheric conditions could be set up over different regions and correction data may be sent to the receivers, thereby significantly enhancing the accuracy.

c) Correcting Multipath Errors

A technique called narrow correlator spacing has been developed to mitigate multipath errors (http://en.wikipedia.org/wiki/Global_Positioning_System). The receiver could recognize the wayward signal and discard it in long delay multipath. Short delay reflections are harder to filter as they are only slightly delayed and their effects are grossly insignificant (http://en.wikipedia.org/wiki/Global_Positioning_System).

d) Correcting Ephemeris Errors

Ephemeris errors could be corrected by modelling, that is, a prediction of what a typical delay might be on a typical day (http://www.trimble.com/gps/index.shtml). Since atmospheric conditions are rarely exactly typical, modelling may not provide very accurate predictions.

2.9. Real – Time Differential GPS

Real-time Differential GPS occurs when the base station calculates and broadcasts corrections for each satellite as it receives the data, that is, as each measurement is received (Chivers, 2003; GeoExplorer, 2005). The correction is received by the roving receiver via a radio signal if the source is land based or via a satellite signal if it is a satellite based and applied to the position it is calculating. Consequently, the position displayed and logged to the data file of the roving GPS receiver is a differentially corrected position.

2.10. Post – Processing Differential GPS

Differential Correction of GPS data by post-processing uses a base GPS receiver that logs positions at known location and a rover GPS receiver that collects positions in the field (Chivers, 2003). The files from the base and rover are transferred to the office processing software, which computes corrected positions for the rover's file. The resulting corrected file can be viewed in or exported to a GIS.

The TerraSync™ software enables the Trimble Geo-XT™ GPS unit to output the PDOP and HDOP values by default together with the latitude and longitude position, elevation number of logs averaged to calculate the position and point identification attributes. The unit also is capable of sub metre accuracy with post-processing correction of the recorded measurements and 3 - 5m accuracy without post-processing correction according to vendor specifications and as confirmed by Serr, Windholz and Weber (2005).

2.11. Basic Skills Requirements in Operating GPS and GIS

GIS requires special skills and technical knowledge to effectively employ and reap benefits of owning it.

Sirait *et al.* (2005) defined GIS as an organized collection of computer hardware, software, and geographic data. Computer hardware, software and geographic data could therefore be referred as individual parts that constitute the whole (GIS).

To operate a GIS requires basic knowledge of operating a computer, basic to intermediate knowledge to work in a relevant GIS software environment and some basic skills to work with databases. Some level of literacy would be advantageous, particularly the ability to read and write in English, being dominant language used.

In communities that are not significantly literate, Participatory GIS (PGIS) could be considered as is usually geared towards community empowerment through measured, demand-driven, user-friendly and integrated applications of geographic information technologies and systems, where maps become a major conduit in the process (Rambaldi, McCall, Weiner, Mbile and Kyem, 2004).

Bujang (2004) presents an example of a community empowerment success story in the case of the Dayak community of Malaysia. The Borneo Resources Institute (BRIMAS) trained and assisted the Dayak community to conduct field surveys and produce their community maps. According to Bujang (2004) initially BRIMAS conducted community-mapping activities using survey equipment such as the compass and tape measurer and later progressed to use GPS units to collect field data.

Community members with senior certificates and some tertiary education could be considered for training in mapping using GPS receivers and working in a GIS. Two weeks to month-long courses could provide community members with the requisite skills, meanwhile such skills could be honed through working with experts.

2.12. Legal Requirements of GPS Accuracy in Land Surveying

In South Africa, the Office of the Surveyor General regulates all survey work and is responsible for overseeing the implementation of the Land Survey Act, 1997 (Act No. 8 of 1997).

In terms of *Regulations Promulgated in terms of Section 10 of the Land Survey Act, 1997 (Act No. 8 of 1997)* ("the Regulations") published in Section 5, *The accuracy with which a survey shall be done is expressed by the following formulae, where-*

Class A refers to-

(i) the determination of reference marks established in terms of regulation 16; and

(ii) such other determinations as may be prescribed in these regulations;

Class B refers to-

(i) the survey of new townships and settlements;

(ii) the resurvey or subdivision of an erf in an existing township or a lot in a settlement;

(iii) the survey for the replacement of a beacon in a township or a settlement; and

(iv) the survey for the preparation of a diagram required under the law relating to the registration of mining titles in respect of precious stones and precious metals;

Class C refers to all surveys not included in Class A or B, and shall include surveys for mining titles in respect of base minerals-

(a) when the position of a point is determined by polars, traverse, triangulation, trilateration, GPS or a combination of these methods, the displacement between any observed ray, measured distance or GPS vector and the equivalent quantity derived from the final co-ordinates of the point fixed shall not exceed-

for Class A: A metres;
for Class B: 1,5A metres;
for Class C: 3A metres;
where A is equal to-

$$0,04 + \frac{S}{30\,000}$$

and S is the distance between the known and the unknown point: Provided that in the case of a GPS vector the comparison is made between the vector derived from the final co-ordinates and the measured vector after the datum transformation has been applied: Provided further that in the case of a traverse the comparison is made to the misclosure of the traverse, where S is the total length of the traverse in metres;

(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;

(c) *when the vertical position of a point is determined, the difference between any determination thereof and the finally adopted height shall not exceed 0,10 metres:*

Provided that the Chief Surveyor-General, in consultation with the Surveyors-General, shall determine a standard of accuracy for any survey operation not specified in this regulation.

The regulations emphasize the significance of sub-metre accuracy in undertaking survey.

2.13. Conventional Survey and GPS Surveying Techniques

Modern technocrats regard GPS surveying technique as the advanced and sophisticated method of survey.

Luo, Ning, Chen and Yang (2005) assert that GPS mapping system is very effective, saves large amounts of time, and material and financial resources as compared to traditional mapping method. Corbley (2005) asserts that when highly accurate location data was required for a project, Sioux Falls had to use GPS units because the conventional survey equipments took a considerable amount of time.

Conventional survey equipment requires highly skilled persons to operate as compared to handheld GPS units that could be used by inexperienced persons with no prior mapping experience (Corbley, 2005). It takes a couple hours to train people in the use of GPS, which makes it fairly user-friendly.

Advanced integrated unit, according to Corbley (2005) combine GPS receiver, antenna and data collector into a handheld device, whereas conventional survey methods use cumbersome systems that involve heavy separate equipment connected by cables.

2.14. The Significance of Participatory GPS-Based Mapping of Communal Land Administration Boundaries

Participatory GPS-based mapping is arguably the desired mapping methodology for mapping communal land. It possesses the potential to produce maps with reliable accuracy, for example by moving through the territory with local people or land administrators, establishing boundaries and identifying key issues using GPS and GIS. It also enhances collaboration amongst the group. The majority of participants in the participatory GIS-GPS-based mapping study in the Ashanti region of Ghana, Trang (2004), were satisfied with the role played by GIS in ensuring successful collaboration amongst the group.

On the other hand, conventional Land Survey mapping poses problems such as spatial and natural resource conflicts. Kyem (2004) asserts that such conflicts could be defined by using participatory GPS- and GIS-based mapping applications. If used for such purposes competing parties should be involved in data collection and analysis to improve communication and enhance conflict resolution.

Trang (2004) illustrated a method of integrating participatory resource mapping and geographic information systems in forest conservation and management. Geographic information tools included participatory resource mapping, ground-truthing by transects walk and GPS, and processing data acquired from participatory process into a GIS for analysis. Lessons learnt from the study are that GIS-enhanced participatory resource maps that were stored and managed in a GIS created a strong advocacy value to local participants, which reflected a learning process and empowerment.

Hile (2004) in her study involving the Asmat families in Indonesia was impressed with the level of significance the members placed on mapping boundaries. The Asmat families declared that through mapping of their lands they became aware of the limitation of their resources and such a realisation encouraged thoughtful usage.

In mapping land held in common it is desirable and proper to involve the majority of members to such land. Participatory mapping tends to produce outputs that are acceptable to parties involved and are credible. Kyem (2001) holds a similar view as he argues that the mapping process should be participatory, with community members being given the opportunity to confirm the actual features on the ground. Mohamed and Ventura (2000) believe current and accurate participatory maps assist indigenous communities to delineate and enhance the security of land rights claims and opportunities to monitor changes in tenure. The participating members delineate land rights and thereby enhance tenure security through provision of testament in favour of or against a claim to a portion of land by an individual or a group. Changes to tenure of land are thus easily tracked and records of transactions could be documented. According to Fox (2002), projects are using participatory mapping tools to develop a deeper and more fully conceptualised understanding of indigenous claims to land.

Kurniawan and Hanafi (2004) in their study of Community Mapping, Natural Resources and Indigenous People Movement in Indonesia argue that knowledge of customary land boundaries and their management is lost, due to the imperfect transfer, from one generation to the next. Participatory mapping of communal lands as envisaged by the CLaRA process will safeguard the heritage by documenting land ownership of these long-neglected areas.

Use of GIS is highly recommended in defining land rights. GIS can explore spatial implications of stakeholders' preferences by identifying areas of overlapping interest and non-overlapping interests (Kyem, 2001). Bersalona and Zingapan (2004) studied the indigenous communities in the Phillipines who used GPS to delineate and reclaim

their ancestral territories. GPS records were used to create accurate three-dimensional maps through an innovative process known as participatory 3D modelling. The participatory 3D modelling initiatives were found to be facilitating cooperation and effective decision making among indigenous communities and government planners in two important fields: land conflict resolution and natural resource planning.

According to Deichmann and Wood (2001), GIS technology provides tools for visualising, integrating, and analysing spatial data and a unique capacity to merge information from many sources. By using a common spatial framework, GIS enables users to analyse how physical, social, and economic factors interact. In the process of visualising, integrating, and analysing spatial data community members should play a role. Participation of local communities helps institutionalise the outputs at local level and provide a legitimacy value to them. Mohamed and Ventura (2000) developed a model that matches technologies and information requirements in tenure related studies. In demarcating indigenous lands they recommend a manual mapping and GPS mapping traditional surveys or GPS surveying.

3. PARTICIPATORY GPS-BASED MAPPING OF UKULINGA FARM

3.1. Introduction

One of the objectives of this research was to develop a Participatory GPS-based 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 an applying the participatory mapping approach.

3.2. The Study Area

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 -29.67°and longitude 30.41° and has an irregular pentagonal shape tilted along the north-west to south-east axis as shown in Figure 2. Note that the topographic farm boundary does not correspond to the cadastral vector boundary overlay (in red) for all parts. The discrepancies may be due to subdivision and/or consolidation activities carried out subsequent to the original farm boundary survey. 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 (Appendix 4) 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.

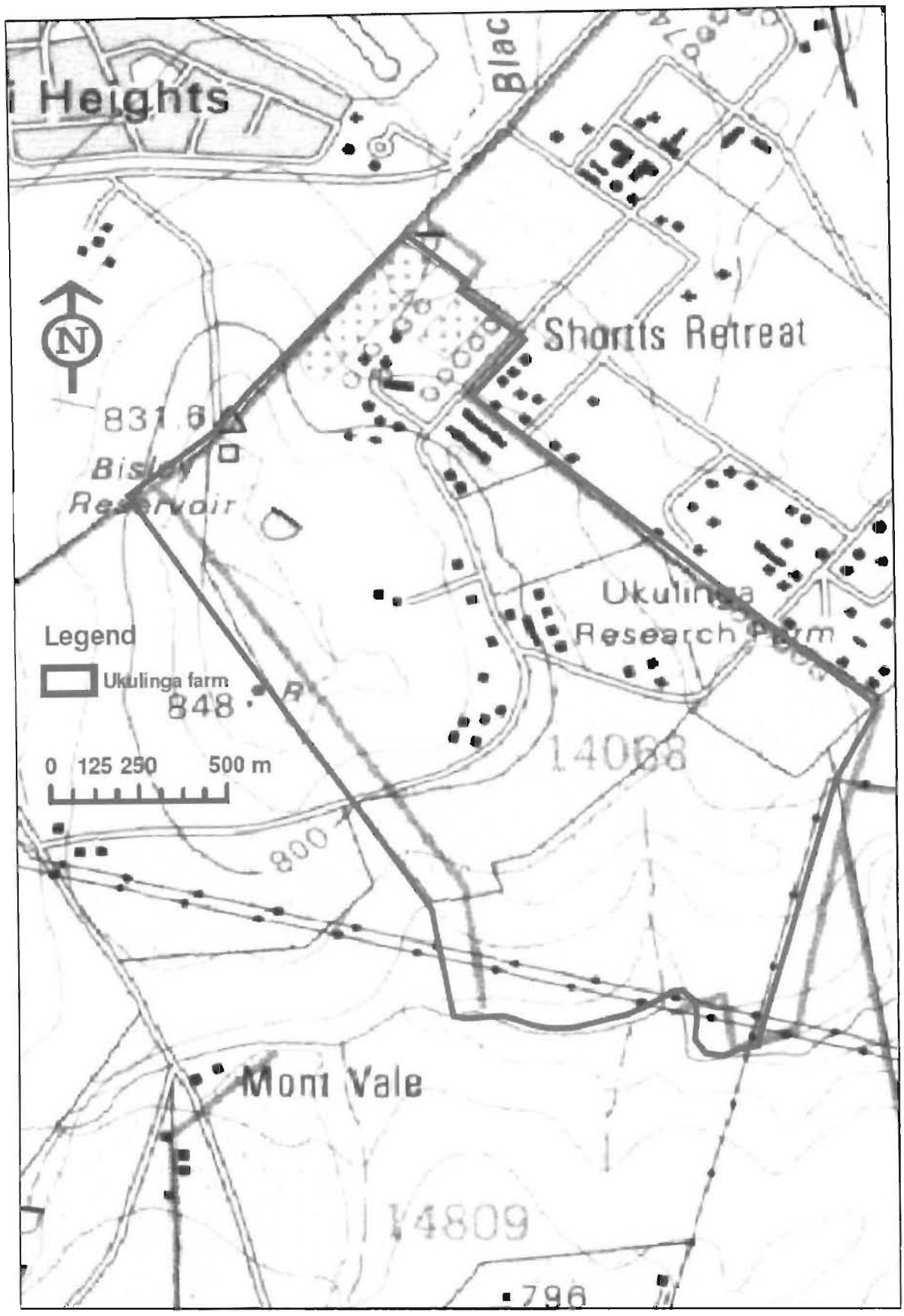


Figure 2. The Ukulinga Research Farm Cadastral Boundary Overlain on a Topographic Map

3.3. Participatory GPS Mapping Methodology

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 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 0.75m), a digital 1:50, 000 topographic map of the area (topo-sheet g2930cb) as well as a vector map of the cadastral boundaries were for reference 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.

The aerial photograph was reprojected to World Geodetic System 1984 (WGS 84) Lo 31 projection, then uploaded to a Trimble Geo-XT™ GPS unit operated by TerraSync™ version 2.10 and used as a survey guide identifying and mapping farm boundary markers.

Differentially corrected GPS coordinates of boundary markers were entered into a GIS overlaid on reprojected aerial photograph of Ukulinga farm to display boundaries. Screen digitizing was conducted to reproduce the boundary by connecting GPS coordinates of boundary marker points and digitally tracing the stream part of the boundary using the ortho-rectified aerial photograph as a backdrop image. A reconstructed boundary map of the Ukulinga farm was the end result.

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 specified in the 1953 survey diagram and in the cadastral map. Figure 3 shows a graphic representation of the recommended Participatory GPS methodology.

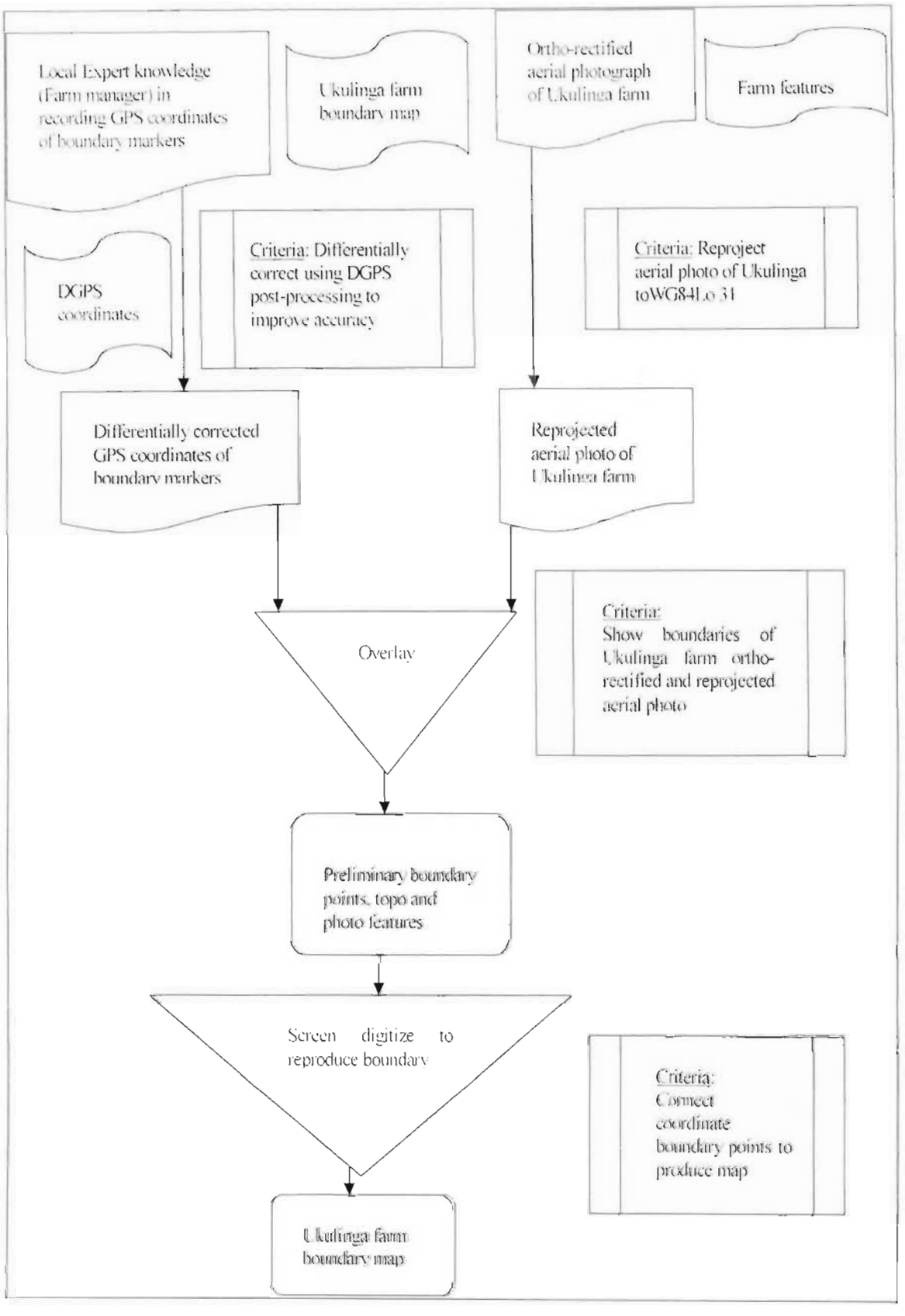


Figure 3. Participatory GPS-based mapping flowchart of the Ukulinga Research Farm

4. Participatory GPS-Based Mapping Results for Ukulinga Farm

4.1. Introduction

The mainly "rail" steel corner post boundary marker points were captured by GPS from 30th October to 1st November 2006 as shown by an attribute Table imported from the Arc GIS 9 ™ software. The survey diagram obtained from the Surveyor General showing original positions of survey beacons was used as 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 recognized 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 digitizing using the ortho-rectified aerial photograph as a backdrop reference image.

However, 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 measured precisely by the Surveyor General's office.

4.2. Accuracy of GPS Measured Trigonometric Beacon Parameters

GPS capture record data for the trigonometric beacon as retrieved from the attribute file of ArcGIS 9® point data after differential correction are shown in Table 2. The comparison became part of the accuracy assessment of the GPS-based mapping exercise.

The GPS measured position of the trigonometric beacon as well as the boundary markers points of the Ukulinga farm discussed later in this section were corrected with the Trimble Pathfinder Office ™ version 3.10 post-processing software using the

Table 2. GPS Captured Data for the Trigonometric Beacon at the North-Western Boundary of Ukulinga

GPS capture data of the Trigonometric Beacon BI-EY230 situated near Ukulinga farm

FID[1]	Max-PDOP[2]	Max-HDOP[3]	GPS HEIGHT[4]	VERT PREC[5]	HORZ PREC[6]	STD_DEV[7]	LATITUDE[8]	LONGITUDE[9]
0	1.8	1.1	829.6	1.8	1.1	0.000524	-29.662847242	30.399079481

Correction Type	Postprocessed Code
Receiver Type	GeoXT 2005
GPS Capture Date	10/31/2006
GPS CaptureTime	03:08:41pm

"Code Processing" differential correction module. This processing type of differential correction uses data from a single base station for each GPS captured position. Base

[1] FID: Field ID
[2] Max-PDOP: Maximum Position Dilution of Precision encountered during GPS point logging
[3] Max-HDOP: Maximum Horizontal Dilution of Precision encountered during GPS point logging
[4] GPS HEIGHT: GPS measured height (MSL)
[5] VERT PREC: Vertical Precision (m)
[6] HORZ PREC: Horizontal Precision (m)
[7] STD_DEV: Standard Deviation (m)
[8] LATITUDE: Latitude (Decimal Degrees - DD°)
[9] LONGITUDE : Longitude (Decimal Degrees - DD°)

station data used in the differential correction procedure were automatically retrieved from the Internet-enabled TrigNet[10] post-processing differential correction of the Pathfinder Office "*wizard*". The "*wizard*" identifies the nearest base station to the survey area from the GPS captured data files. Differential correction data from the Pietermaritzburg base station, located in the city centre some 7km from the study area at latitude 29°36′02.62600″ S, longitude 30°22′59.75930″ E and altitude 743.99 metres above sea level were retrieved and used in the differential correction process.

The position variables shown in Table 2 indicate the precision attained in the GPS measurements. The table shows values of the measured Height (in Metres above Sea Level), Latitude and Longitude (in Decimal Degrees), maximum values of Positional Dilution of Precision (PDOP) and Horizontal Dilution of Precision (HDOP) encountered during GPS logging of each point and the respective calculated Vertical and Horizontal Precision as well as the Standard Deviation. The latter values represent the largest errors encountered during the GPS repeated measurement of the same point. In this case maximum PDOP and HDOP showed low scalar values of 1.8 and 1.1 and the associated Vertical and Horizontal Precision (or standard error) values in the same magnitude of 1.8m and 1.1m respectively.

The overall Standard Deviation of 0.0005m at 68% confidence level indicated that the GPS measurement of height and position coordinates was highly precise. The standard deviation, calculated as the square-root of the summed differences (deviations) from the mean of repeated measurements divided by the number of measurements made for the same observation, is a well established indicator of the precision and accuracy. The lower the standard deviation, the higher the precision or accuracy of measurement depending on whether the deviation is from a measured mean or from a true mean.

[10] TrigNet is a acronym for South Africa's Network of Permanent GPS Base Stations under the administration of the Chief Directorate Surveys and Mapping.

Comparison of coordinates and height of the trigonometric beacon provided by the Surveyor General with those captured by the GPS (Table 3) showed a minor

Table 3. Comparison of Trigonometric Beacon Measurements

	Trig Beacon BI – EY 230 Coordinates				
	Surveyor General Data	GPS Data	Absolute Difference (m)	Displacement (m)	Percent Difference
Elevation	832.8	829.6	3.2	$S=v(\Delta X^2+\Delta Y^2)$	0.38
Latitude	29.6628	29.6628	0.0000	0.0002	-
Longitude	30.3989	30.3991	0.0002		

$$S = \sqrt{\Delta X^2 + \Delta Y^2} \quad \text{(Equation 1)}$$

difference of 3.2m in elevation representing a vertical error of 0.38% and a displacement representing a horizontal error of 0.002m. 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 is being magnitude of deviation from these values. Displacement representing the error between the two values was calculated basing on the Pythagorean equation shown in equation1.

The survey regulations for GPS accuracy discussed earlier in this thesis stipulate that for reference marks, the displacement S, between the known and unknown (GPS measurement) point should not exceed a tolerance value denoted by A=0.04* (S/30000). The A-value was found to be 0.0400m or 40mm. The 0.2mm error obtained by the GPS measurement was therefore well within the tolerance levels set by the Survey Regulations.

4.3. Accuracy of Area Derived from GPS Measured Boundary Markers

A record of GPS capture data for the Ukulinga farm boundary markers as retrieved from the ArcGIS 9® point attribute file following code post-processing differential correction is displayed in Table 4. The differential correction record shows that the overall quality measurement of points by GPS based on the calculated 68% confidence level standard deviation for each measured point was very good. As

Table 4. GPS Point Data Captured from Attribute File of Boundary Markers Imported from ArcGIS 9® *Shape File*

GPS captured proxy survey beacons of the original Ukulinga farm

FID	Max-PDOP	Max-HDOP	HEIGHT	VERT PREC	HORZ PREC	STD_DEV	LATITUDE	LONGITUDE
0	2.1	1.0	833.4	2.1	1.0	0.000321	-29.662862911	30.399098814
1	3.9	1.7	760.8	3.8	1.6	0.000271	-29.675158043	30.403983246
2	2.7	1.3	723.0	2.5	1.3	0.000239	-29.678296408	30.412577423
3	5.6	2.4	776.6	2.9	1.7	0.000329	-29.672066885	30.414496598
4	5.7	2.8	776.5	3.7	1.9	0.000352	-29.670292775	30.415551929
5	3.2	1.8	785.5	3.8	2.0	0.000244	-29.664071582	30.407348922
6	3.2	1.8	782.1	2.9	1.8	0.000334	-29.664081048	30.407331095
7	5.7	1.9	777.5	6.2	1.9	0.000362	-29.668245127	30.412854524
8	5.8	1.7	776.5	4.1	2.0	0.000233	-29.668273855	30.412884821
9	5.9	1.7	777.5	3.0	1.8	0.000355	-29.668293214	30.412868416
10	3.5	1.9	813.0	2.5	1.6	0.000356	-29.665682961	30.396996061
11	2.3	1.5	801.0	2.2	1.7	0.000357	-29.664905966	30.396413947
12	7.9	3.1	755.7	3.7	1.9	0.000862	-29.658342624	30.403583571
13	3.0	1.5	759.0	3.0	1.6	0.000823	-29.658830762	30.403123893
14	2.6	1.5	756.3	2.5	1.5	0.000309	-29.658398953	30.403660952
15	2.0	1.0	760.7	1.9	1.0	0.000397	-29.659827950	30.404989637
16	3.7	1.8	760.0	3.6	2.0	0.000834	-29.659615573	30.405259435
17	2.7	2.2	773.7	2.2	2.4	0.000687	-29.661263606	30.406504095
18	6.0	3.6	769.0	3.5	2.2	0.001670	-29.660987453	30.406599321
19	1.8	1.1	772.7	2.1	1.4	0.000550	-29.661193939	30.406580183

Correction Type	Postprocessed Code
Receiver Type	GeoXT 2005
GPS Capture Date	8/9/2006

shown in Table 4, standard deviations for all points captured were below 0.001m except the point with Field ID (FID) 18 with as standard deviation approaching 0.002m. Although the GPS PDOP was set to the recommended maximum of 6 (maximum PDOP tolerance <6), it became necessary to relax the PDOP tolerance at

two instances (FID 12 and 18 showing maximum PDOP values ≥6) during capture when boundary markers were obstructed by tree canopies. This however did not yield the poorest precision in comparison with other points as can be seen in Table 4.

As mentioned previously, no survey beacons as described in the original survey diagram could be recognized 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. A reconstructed map of the Ukulinga farm overlaid on the ortho-rectified image is shown in Figure 3. It was assumed that the small difference between the survey diagram area and the cadastral area of 615ha was due to the probability that the cadastral data had been updated for the additions to the farm. Table 5 features a comparison of the areas showing a difference of 0.2409ha representing a 0.12% overestimate error between the GPS derived area

Table 5. Comparison of the GPS Derived Area and the Cadastral Record with the Area Recorded in the Survey Diagram of December 1953

Ukulinga Research Farm Area Survey Comparisons

Survey Data Source	Area (ha)	Absolute Difference (ha)	Percent Difference
Survey diagram (ha) - 1953	209.3871	-	-
Cadastre (farms) (ha) - -	209.4486	0.1794	0.09
GPS derived (ha) - 2006	209.6280	0.2409	0.12

and the area recorded in the survey diagram. A difference of 0.1794ha representing a 0.09% overestimate error with the cadastral area. According to a study conducted by Irrigation Training and Research Centre (1998), an error of less than 1% in area measurements was considered of high accuracy. The study states that errors of less than 3% can be expected when mapping on a good quality ortho-rectified image and less than 2% when using a sub-meter GPS. The study also commended combined approaches of mapping areas as adopted in this study to be likely to yield the best results. The participatory GPS based methodology proposed in this study therefore seems to be viable.

Figure 4. Ukulinga Farm Boundary Derived from GPS Captured Points Against an Ortho-rectified Aerial Photograph Backdrop

5. ANALYSIS AND MAPPING OF BASIC COMMUNAL LAND ADMINISTRATION SYSTEMS

5.1. Introduction

The Makurung Village case study is undertaken to understand basic communal land administration systems. It is the objective of this study to provide an analysis of basic communal land administration systems for possible recommendation to CLaRA implementation.

5.2. The Study Area

The area of study is Makurung Village, a communal area under the jurisdiction of Bakgaga Traditional Authority. The village is centred at Latitude 24°21′ and Longitude 29°32′. The area forms part of gaMphahlele (generally referring to the land area within Bakgaga Traditional Authority's jurisdiction) in the Lepelle-Nkumpi Local Municipality. Lepelle-Nkumpi Local Municipality is one of the five municipalities of the Capricorn District Municipality. Capricorn District Municipality is one of the four district municipalities making Limpopo Province. It is situated at the centre of the Limpopo Province where the capital city, Polokwane, is located. Limpopo Province is found at the northern part of South Africa, sharing national borders with Zimbabwe, Botswana and Mozambique.

5.3. Mapping with Global Positioning Systems (GPS) and Geographic Information Systems (GIS)

Members of Makurung Communal Land Administration Team composed of the headman, a member of the headman's family (brother) and the headman's Secretary were asked to define the boundaries of their land administration area. A hard copy of a 1:50,000 topographic map was used to identify the boundaries of the communal land administration area. Boundaries that could be identified on the map were marked

as the Communal Land Administration Team identified them on the topographic map. The boundary identification and marking exercise was followed by a tour by the Researcher and members of the Communal Land Administration Team driving along accessible parts of the boundary of the land administration area and taking other paths where boundary markers are not accessible.

A Trimble Geo-XT™ hand-held GPS unit was used to record coordinate points marking the communal land administration boundaries. The GPS unit, operating with TerraSync™ software, was set to World Geodetic System 1984 (WGS 84) and to the Geographic Coordinate System (GCS) in latitude and longitude decimal degrees to map Makurung Village.

The recorded GPS coordinate points of boundary markers were entered into GIS overlaid on a Geo-referenced tagged image format to produce a Raw Data Map.

A screen digitization application was conducted on the Raw Data Map connecting boundary markers thus creating a boundary vector map. The final map of Makurung Communal Land Administration was then produced. A flowchart representing the GIS operations conducted in mapping Makurung Basic Communal Land Administration area, is presented below:

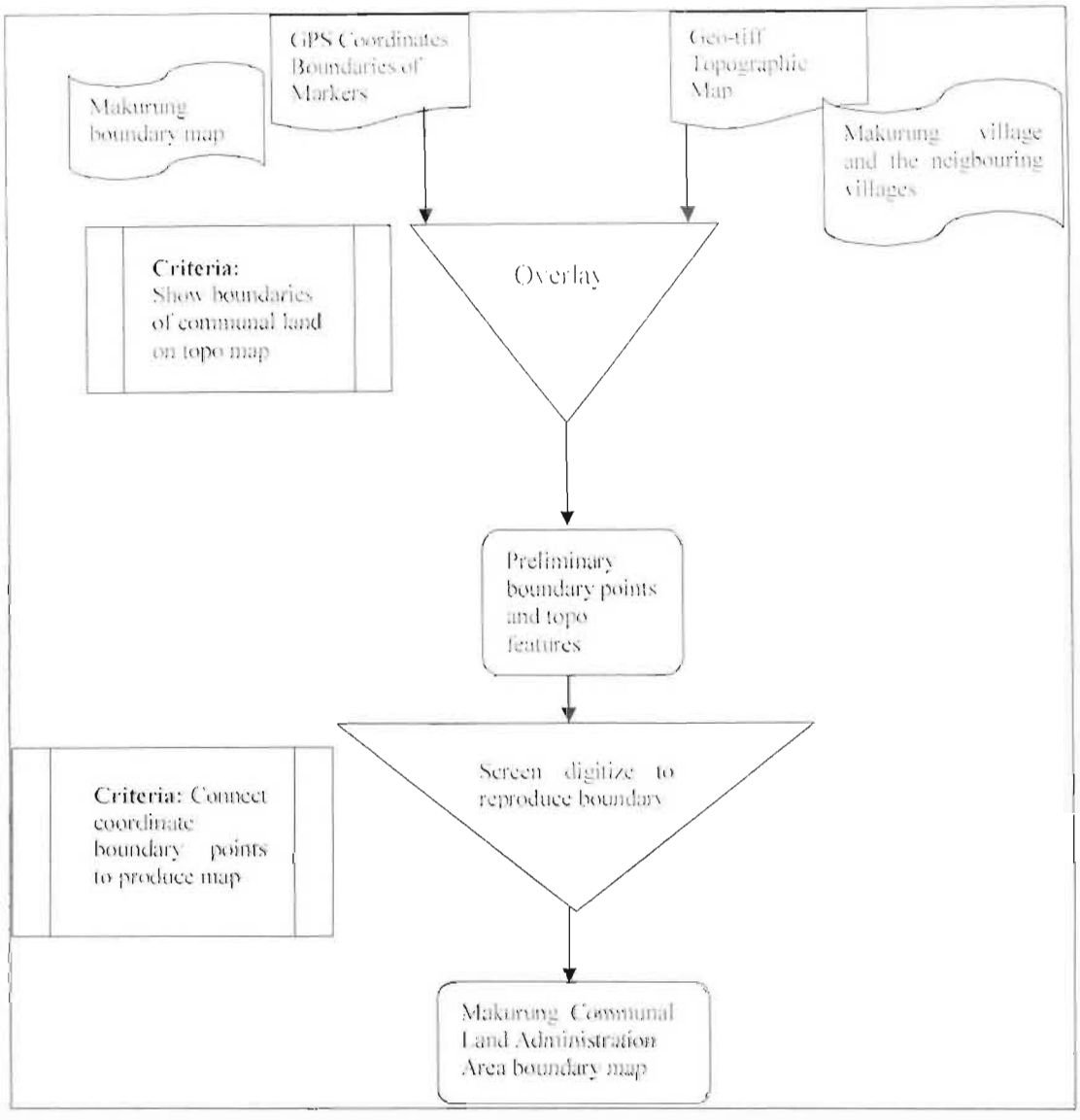


Figure 5: Flowchart: GPS-based Mapping Operations of Land Administration Systems in a GIS

5.4. Interviews

The Makurung Land Administration Team and the Bakgaga Traditional Authority were interviewed on land administration, respectively. They explained their land administration structure, individual components making up the structure and the responsibilities of each component. The land administration teams also provided detailed explanation on the functioning of the system, as a whole and not parts in a whole. Data obtained from the interviews was then analysed and then a clarified conventional system of communal land administration presented.

5.5. Analysis

Participatory GPS- and GIS-based mapping is a logical step by step process and requires particular data sets to accomplish. The flowchart represented by Figure 5 provides the data sets requirements, GIS operations pertinent to and the subsequent output of the process.

6. DATA ANALYSIS: MAPPING OF BASIC COMMUNAL LAND ADMINISTRATION SYSTEMS

6.1. Introduction

This chapter focuses on the analysis of responses obtained from interviews with Makurung Land Administration Team and Bakgaga Traditional Authority on the operation of their Communal Land Administration Systems. The analysis would clarify on the workings of the said systems. Attention is also directed at the Participatory GPS mapping exercise undertaken with the Makurung Land Administration Team.

Questions posed to Makurung Land Administration Team were mainly on how land allocation requests are processed, on transfer and registration of land rights, on the structure and system of their land administration and on what they deem as challenges facing the system. Bakgaga Traditional Authority responded to a different set of questions relating to the broader operation of the land administration system. Appendix 1 and Appendix 2 represent questions posed to Makurung Land Administration Team and to Bakgaga Traditional Authority, respectively. Data collected through participatory mapping is also presented and an analysis is given.

6.2. Interview Data: Makurung Land Administration Team

Induna Shogole and members of the Makurung Land Administration Team were interviewed on their communal land administration practices. The following are their responses to the questions asked:

6.2.1. Land Allocation Procedures

According to Makurung Land Administration Team, an applicant approaches the Induna in a particular ward for a residential/crop field site, either having identified a site or prior to site identification. If an applicant is from another area outside the

jurisdiction of the Induna, it is incumbent upon the person applying for a site to be in possession of a release letter from the previous Induna that serve as a testimonial. Such letter should, among other issues, indicate that he or she co-operated and worked soundly with them. It is highly unlikely that a person with a bad record could be accepted to become a member of the tribe or community.

As a matter of procedure, foreigners are illegible for site allocation. Only male foreigners married to a local woman could be allocated a site. It should, however, be noted that the allocated site would then be registered in the name of the local spouse.

On availability of a site, the Induna issues a letter to the applicant, sending the applicant to the Tribal Secretary's office. The letter recommends to the Tribal Secretary that the site in question be allocated to the applicant. At the Tribal Secretary's office an application form is then completed, signed and stamped by the Secretary and forwarded to the Department of Agriculture. An official of the Department of Agriculture completes the relevant Section and then forward the form to Department of Local Government and Housing for registration of a Permission To Occupy (PTO). The applicant is then issued with a PTO, which serves as prove that the site occupant is a legally recognized occupant.

6.2.2. Recording of Land Rights

Makurung Land Administration Team records land rights of its citizens. It is acknowledged that such records are not kept up to date, particularly the sites acquired through inheritance. The reason for the poor record keeping in that regard is because the land administration team is not warned of such changes and there are no available regulations that compel recipients of such properties to inform and register those changes with the land administration system. The land administration system gets to know of them when a dispute is lodged with their office.

6.2.3. Transfer of Land Rights

Community rules provide for a possible transfer of land rights from among members of the community on both residential and crop-field sites. Members could exchange or give land rights on a particular site or portion of land to any other member of community, following the set procedures. The affected parties should have an agreement on the proposed transfer that which could be temporary/seasonal or permanent. Parties to the agreement would then jointly present their agreement to the land administration team for consideration.

If the Induna and the land administration team ratify the application for permanent transfer of rights, then a similar procedure to the one on land allocation is followed. The site will then be registered in the name of the new occupier.

Transfer of rights could be effected as a result of land rights inheritance. As a natural practice, the youngest son in the family inherits the site whereon the household is built. However, now of recent, families are flexible on inheritance allowing any child to inherit. The family could nominate any child, particularly the indigent child to be the one to inherit family estate by concurrence.

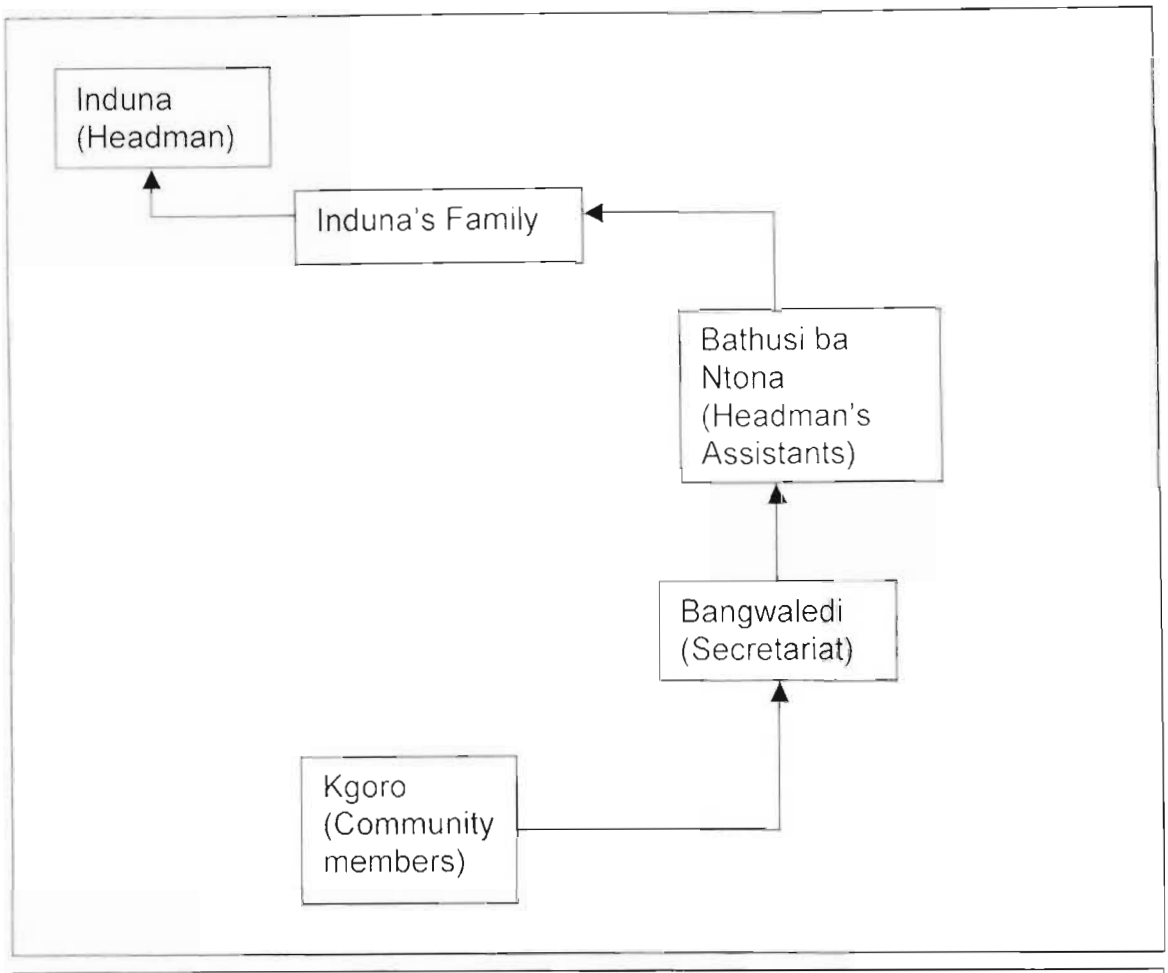


Figure 6: A Graphic Representation of Makurung Land Administration System Responsible for Makurung Village, gaMphahlele, Limpopo

6.2.4. Challenges Facing Makurung Land Administration System

Makurung Land Administration System is plagued by three major problems. Firstly, there are illegal occupiers of land who did not follow the set application process to acquire land. Several households illegally occupy land close to a graveyard. Illegal occupiers were reported to Bakgaga Traditional Authority. A case is yet to be resolved.

Secondly, Makurung Land Administration System is in dispute with Dithabaneng community over ward boundary. According to Makurung Land Administration System the Dithabaneng community claims almost half of their land area. Both communities

are members of Bakgaga Ba Mphahlele Tribe falling under the administrative jurisdiction of Bakgaga Traditional Authority. Bakgaga Traditional Authority is asked to mediate in the conflict and the matter is currently before the tribal court. It is hoped that the case will soon be resolved. Among the contestations raised by the Dithabaneng community is that they had contributed towards the purchase of the farms currently under the jurisdiction of Makurung Land Administration System and therefore have a rightful claim to the properties. The fact that Makurung Land Administration System's land area is made of bought farms complicates the matter and will require a well-thought solution that will address future claims likely to arise from other communities of the Bakgaga Ba Mphahlele Tribe who are currently not residents of Makurung Village.

Thirdly, Makurung community and Dithabaneng community are at loggerheads over control of the Agricultural project currently administered by the Makurung community. According to Makurung community the agricultural project is located on land that they formerly used as crop-fields. Makurung Land Administration System allocated and administered those crop-fields before the launch of the agricultural project. In the late 1980s a development project constituted by members of both communities recommended to the Makurung Land Administration System that an agricultural project be launched to optimally utilize the land. In the late 1990s the Dithabaneng community felt that the project is on their land and should have a stake in its administration. Reasons advanced by the Dithabaneng community are similar to those raised under boundary dispute. Solutions to the boundary dispute may help resolve the dispute over administration of the agricultural project.

6.3. Bakgaga Traditional Authority

6.3.1. Introduction

The Bakgaga Traditional Authority exercises authority over fourteen (14) basic land administration systems of which Makurung form part. Below is their response to the questions seeking to understand how their land administration system operates:

- Applicant approaches Induna in the area.
- Induna, on availability of a site and the applicant satisfying the set allocation criteria, issues a letter to the applicant.
- Applicant takes a letter to the Tribal Secretary's office.
- Tribal Secretary completes a form, signs it and put a stamp of approval.
- Application is forwarded to the Municipality for the issuance of a PTO.
- Municipality issue PTO in favour of the applicant.
- Municipality request local Department of Agriculture to demarcate a crop field.

6.3.2. The Hierarchical Structure of Bakgaga Traditional Authority's Land Administration System

(a) The Chief or Chieftainess

The Chief or Chieftainess is the head of a particular tribe and also that of an established tribal authority ruling over a number of villages within whose area of jurisdiction a number of Indunas exercises their authority. Chieftainess NS Phatudi Mphahlele with several Indunas serving under her leads the Bakgaga Traditional Authority. Her role as a traditional leader is to perform functions provided for in terms of customary law and customs of the traditional community and as per applicable legislation (e.g. as per provisions of Section 20(1)(a)-(n) of Traditional Leadership and Governance Framework Act, 2003 (Act 41 of 2003)).

(b) Senior Mokgomana

The Senior Mokgomana is the second-in-command, the Chief or Chieftainess' assistant and confidante. His or her duties are, amongst others, the collation of reports from various structures that make-up the tribal authority such as Bakgomana, tribal court and tribal council and to update the Chief or Chieftainess on all matters. All administrative matters relating to land and governance of Indunas are reported to him or her to be taken to the Chief or Chieftainess. According to protocol the Indunas communicate with the Chief or Chieftainess through the Senior Mokgomana. Senior Mokgomana regularly meets the Tribal Secretary to discuss matters of concern to the tribe.

(c) Tribal Secretary

The Tribal Secretary is a public servant, serving the tribe at the tribal office. He or she serves as an administrator responsible for, amongst other duties, the safekeeping of legal contracts with third parties doing business within the area of jurisdiction of Bakgaga Traditional Authority, act as a Commissioner of Oath, administer tribal funds and reconcile cashbooks. He or she reports directly to the Chief or Chieftainess on matters relating to his or her functions.

(d) Bakgomana

Bakgomana are appointed by the Chief or Chieftainess to assist in the administration of the traditional authority. They are mostly ordinary members of the society who are enlightened or may be members of the royal house who are deemed to possess capacity to contribute positively to the administration. Their duties are amongst others, to look after the welfare of the royal kraal, to preside over civil cases brought before the tribal court and to advise and provide support to the Chief or Chieftainess.

(e) Tribal Council

The tribal council is constituted by community elected councillors, Senior Mokgomana and all Indunas in the area of jurisdiction of the tribal authority. The roles of the tribal council are, amongst others, to administer affairs of traditional communities in accordance with customs and traditions, to assist, support and guide traditional leaders in their performance of functions, to support municipalities in identifying community needs, and to perform all duties as prescribed by Section 4(1) of the Traditional Leadership and Governance Framework Act, 2003 (Act 41 of 2003).

(f) Tribal Treasurer

The tribal Treasurer reports to the Tribal Secretary. He or she is a public servant responsible for handling finances of the tribal authority. He or she also assists the Tribal Secretary in performance of some of the administrative duties.

(g) Tribal Court

The tribal court adjudicates over land-related and social matters. Bakgomana are actively involved in the administration of court activities. Senior Mokgomana or the Chieftainess or Chief in exceptional cases, act as the judge of the tribal court. The court does not have jurisdiction over criminal matters. Criminal cases are reported to the South African Police Services and are dealt with in the magistrate court.

(h) Induna

An Induna is a traditional leader exercising authority within the area of jurisdiction of a Chief or Chieftainess in accordance with customary law. Induna reports to the Senior Mokgomana on all matters relating to land administration and governance. By virtue of their positions, Indunas are automatic members of the tribal council.

(i) Induna's family

The Induna's family provide support to the Induna and look after the interest and welfare of the family in accordance with customary law. The family is responsible for selecting the hire to the throne.

(j) Induna's Assistants (Bathusi ba Ntona)

Induna has the right to select his or her assistants in accordance with customary law. The appointed assistants help the Induna in his/her daily administration. She or he consults with them before making any decisions whereas reserving the right to make a final decision. Guests and applicants for sites will go through the assistant as a matter of protocol and not approach the Induna directly. Alternatively the Induna may not discuss any request with a guest in the absence of an assistant.

(k) Secretariat (Bangwaledi)

The community appoints the Secretariat to serve them in the office of the Induna. The Secretariat is responsible for issuing letters to applicants of sites, which are then taken to the Tribal Secretary for processing. The Secretariat also records resolutions of the kgoro (community meetings) or judgements of the local court.

(l) Kgoro (Community members)

Community members older than eighteen years may sit at the community gathering to discuss matters of interest to the community or to make inputs towards the resolution of a dispute brought before the Kgoro. It is at the Kgoro where community members receive updates of the latest developments relating to their community or tribe at large. The Bakgaga Traditional Authority has given special orders that every Induna

should call the Kgoro sitting at least once a month to communicate with, or update, the community of the latest developments.

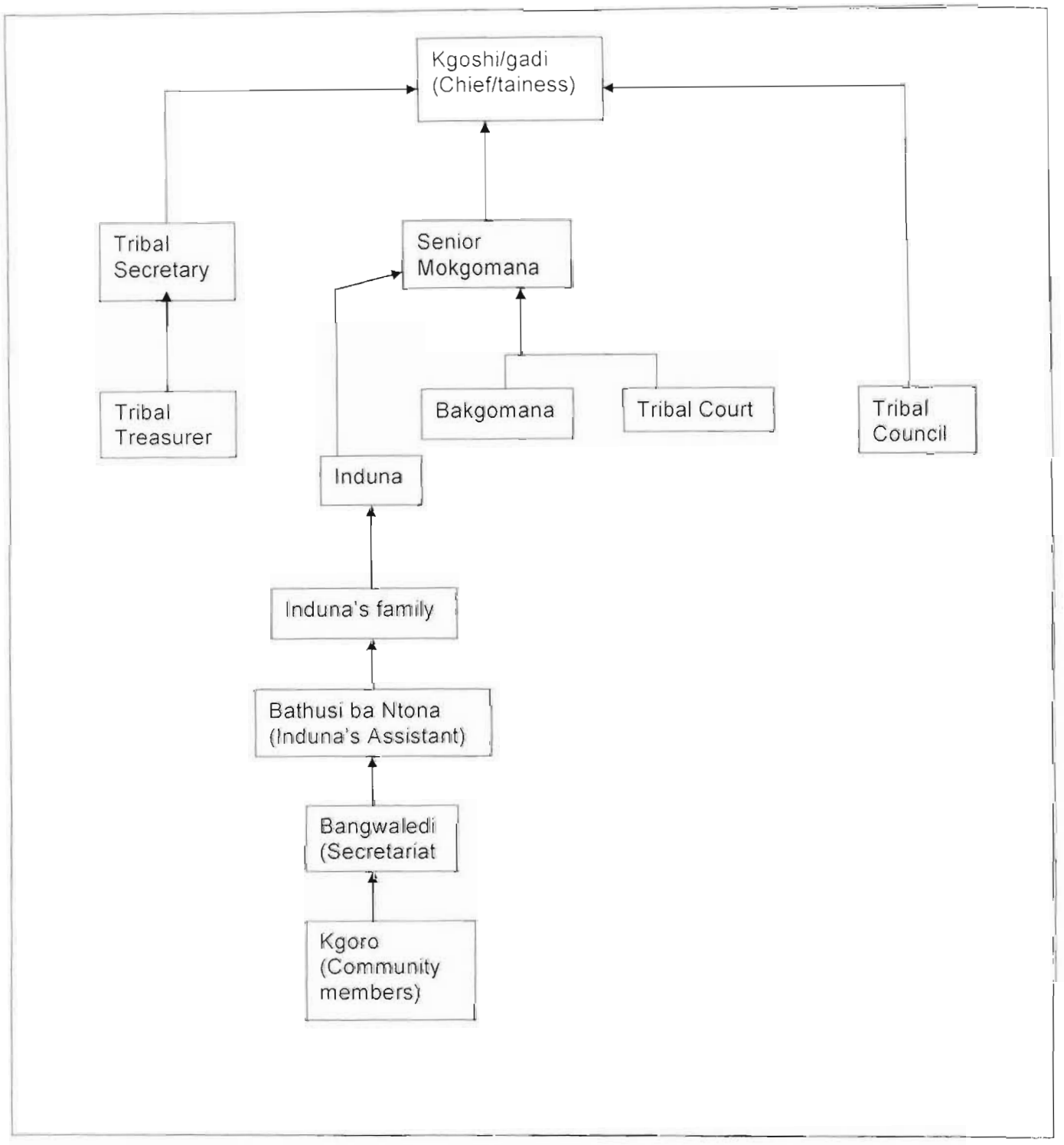


Figure 7: Hierarchical Structural Representation of Bakgaga Traditional Authority

6.4. ANALYSIS OF INTERVIEW RESPONSES

Table 6: A Comparative Analysis of Land Administration Procedures According to Bakgaga Traditional Authority and Makurung Land Administration System.

Bakgaga Traditional Authority	Makurung Land Administration System
Applicant approaches Local Induna for a site.	• Applicant approaches Induna for residential site or crop field either having identified a site or prior to site identification. • If applicant is from another area outside the jurisdiction of the Induna, the person should have a release letter from the previous Induna indicating that he or she co-operated and worked soundly with them.
Induna, on availability of a site and the applicant satisfying the set allocation criteria, issues a letter to the applicant recommending site allocation.	Upon availability of site, a letter is issued to the applicant, sending the applicant to the Tribal Secretary' office.
Applicant takes the letter to the Tribal Secretary's Office.	Applicant takes the letter to the Tribal Secretary's Office.
Tribal Secretary completes a form, sign it and put approval stamp.	Application form is then completed and is signed and stamped by the Secretary.
Applicant forwards the stamped form to the local municipality requesting that a PTO be issued in favour of the applicant.	Applicant forwards the completed form to the Department of Agriculture.

Bakgaga Traditional Authority	Makurung Land Administration System
Municipality issues a PTO in favour of the applicant.	Department of Agriculture completes the relevant Section and then forwards the form to Department of Local Government and Housing.
If the allocated site was not earlier demarcated the municipality will approach the local Department of Agriculture to demarcate the site on behalf of the applicant.	Department of Local Government and Housing issue a Permission To Occupy (PTO) in favour of the applicant.

6.4.1. Land Allocation Procedures

Procedures for the allocation of communal land as elucidated by the Makurung Land Administration Team and Bakgaga Traditional Authority illustrate some areas of commonality and congruence. There is consensus on the first stage of the application process which is a "*knock at the door*" at Induna's place. The Induna, together with administrators, is better placed to know of available land for allocation as requested by the applicant. The applications will at that level be put under scrutiny, to verify compliance with the set land allocation criteria and community rules.

The Induna sends his or her assistant to show the qualifying applicant a site due for allocation. If the applicant finds the site suitable, a letter is issued in favour of the allocation, to be submitted to the Tribal Secretary to proceed with the processing of the application. It is the responsibility of the applicant to take the letter to the Tribal Secretary's office and subsequent correspondences to all the other authorities until the final stage is reached.

The two administration authorities concur on the step that follow where the Tribal Secretary completes a form, append signature and put approval stamp to it. Again the

applicant ensures that the approved form reaches the next level within the administration hierarchy. However, there is lack of clarity as to which authority becomes responsible to further process the application. According to the Makurung Land Administration Team the application is then forwarded to the Department of Agriculture, whereas, Bakgaga Traditional Authority asserts that the local municipality is the responsible authority to oversee the application. Both authorities agree on the purpose of the submission that being to obtain a Permission To Occupy (PTO). It should, however, be noted that PTOs currently issued outside KwaZulu-Natal are legally invalid owing to the withdrawal by the Minister of Land Affairs of the initial authority given for that purpose to the MEC for Local Government and Traditional Affairs. Any PTOs, which have been issued by the various persons, institutions and structures since the 27th April 1994 are not legally valid with the exception of the KwaZulu-Natal province (Sibanda, 2006).

The withdrawal by the Minister of Land Affairs of the authority to issue PTOs has created an administrative vacuum and a breakdown in administration of communal land. Due to lack of communication between government and traditional authorities PTOs are continuously being issued, albeit illegally. Government is challenged to close the administrative vacuum created by the withdrawal, lest communal land administration remain chaotic.

The confusion in the process beyond the Tribal Secretary could be ascribed to the fact that, at local level, the Makurung Land Administration System issue a letter of recommendation to the applicant for submission to the Tribal Secretary and are therefore ignorant of subsequent processes. The Bakgaga Traditional Authority, by virtue of being a referring institution, knows exactly which institution is responsible for considering the application. In the spirit of improved service delivery and Batho Pele, People First policy, it is imperative that institutions providing services should be informed and be adequately capacitated to better serve their clients. Bakgaga Traditional Authority should communicate the process followed in site allocation to basic Communal Land Administration Systems within their area of jurisdiction.

6.4.2. Comparative Analysis of the Role Played by Communal Land Administration System and that to be Played by the Envisaged Land Administration Committee

Five subtopics are discussed below to unpack how the current situation in communal areas is likely to influence the implementation of CLaRA. It is the objective of this study to provide a generic framework towards implementing the Act. Focus is directed to the analysis of the structural composition of the Communal Land Administration System, inherent decision-making processes, the processes leading to the development of community rules, how land rights are been recorded and the role played by gender in land allocation.

6.4.3. Analysis of the Structural Composition of Communal Land Administration System against Land Administration Committee Envisaged by CLaRA.

Bakgaga Traditional Authority is made up of fourteen (14) basic communal land administration areas led by an equal number of Indunas. All but one of the Indunas is female. Five administrators constitute Makurung Village's Land Administration System. Only one of the five administrators is female. The dominance of land administration by male members could be attributed to the fact that African societies are patriarchal in nature where female members were not considered for leadership roles and had to take a back seat and trust their male counterparts to provide leadership. Bakgaga Traditional Authority is led by a female, Chieftainess NS Phatudi Mphahlele. She is expected to raise a son who will upon maturity assume the throne.

The Communal Land Rights Act, 2004 (Act No.11 of 2004) advocates a representative Land Administration Committee. In terms of Section 22(3) of the Act at least one third of the total membership of a Land Administration Committee must be female. One member of the Land Administration Committee should represent the interests of vulnerable community members, including women, children and youth, the elderly and the disabled (Section 22(4) of Act No. 11 of 2004).

The scenario painted by the above deliberations calls for an overhaul of the current system of communal land administration to align with the prescripts of the Act. The Makurung Communal Land Administration System's female representation is currently at one fifth. The challenge is to find willing women to take up positions in land administration and for men to accept the changes and support women in their new roles.

6.4.4. Decision Making Processes

The current system of communal land administration provides for, although to a limited extent, democratic decision making. The Chief or Chieftainess consults with the tribe on matters that affects the tribe or assets belonging to the tribe. A tribal gathering (Kgoro) is called to discuss matters of common interest. Community structures such as the tribal council (a structure constituted by community-elected councillors and Indunas) play a role in enhancing democratic decision making. Its role is to administer affairs of traditional community in accordance with customs and traditions, to assist, support and guide traditional leaders in their performance of functions and to perform all other duties as prescribed by Section 4(1) of the Traditional Leadership and Governance Framework Act, 2003 (Act No.41 of 2003). The tribal council and the Kgoro are two important forums that present an opportunity for community members to influence decisions on matters of common concern. It should, however, be noted that the interests represented will be largely determined by the composition of the structure.

According to Bakgaga Traditional Authority instructions are issued to all Indunas to hold Kgoro at least once in a month. The monthly meetings are meant to communicate matters relating to the tribe obtained from the Bakgaga Traditional Authority and to also provide a platform for tribe's people to input on governance and register their concerns on matters of interest.

In terms of the provisions of the Communal Land Rights Act, 2004 (CLaRA) the community must make and adopt its community rules and have them registered (Section 19(1)). CLaRA advocates governance by the people. Community rules must regulate the administration and use of communal land by the community as landowner within the framework of law governing spatial planning and local government (Section 19(2) (a) of Act No. 11 of 2004). Public participation in the making and adoption of community rules ensures democratic governance. The elected leaders will be compelled to govern in the spirit of and guided by the community rules. The leaders become community servants with the responsibility to constantly consult with their masters, the community.

6.4.5. Community Rules Development Process

The Makurung community has established community rules. These community rules are, however, not documented. They are verbally passed on from one generation to the next with necessary amendments effected over time. Community rules are visited whenever the need arises or when there are new challenges to come to grips with.

Section 19 of the Communal Land Rights Act provides for public participation in the making and adoption and registration of community rules. The adopted community rules are binding on the community and are deemed a matter of public knowledge on registration. Systems are put in place to ensure that the community rules are not in conflict with the Constitution and CLaRA (Section 19(4)). Community rules may be amended or revoked by a community in a general meeting and in a manner applicable to their adoption (Section 20(1)). Democratic participation is advocated in the drafting, adoption, registration and amendment and revoking of community rules.

6.4.6. Recording of Land Rights

Data collected from Makurung Communal Land Administration System indicates that land rights are recorded and such a record is properly kept, although to a limited extent. All persons legally occupying site at Makurung have their land rights recorded and are in possession of a Permission To Occupy (PTO) certificate. It has been noted that inherited land rights are not properly recorded. There is currently no community rule in existence that compels people inheriting land rights to record such transactions to Makurung Land Administration System for entry in the land register. Makurung Land Administration Committee should consider closing the rules gap as a matter of urgency. At present the land administration system gets to know of inherited land rights when a dispute is registered over those sites.

The CLaRA implementation is expected to ameliorate the situation. Section 24(3) (a) (i), (ii) provides guidelines with regards to allocation of new order rights on communal land. Section 24(3) states, "*In the exercise of its powers and the performance of its duties a Land Administration Committee administration must-*

(a) take measures towards ensuring-

(i) the allocation by that committee, after a determination by the Minister in terms of Section 18, of new order rights to persons, including women, the disabled and the youth, in accordance with the law;

(ii) the registration of community land and of new order rights;

(b) establish and maintain registers and records of all new order rights and transactions affecting such rights as may be prescribed or as may be required by the rules"

Section 24(3) (b) compels the Land Administration Committee to establish and maintain registers and records of all new order rights and transactions of such land as prescribed or required by rules. CLaRA advocates the registration of land rights and

land transaction relating thereto. Such records will enhance land rights holders tenure and serve as a useful resource in adjudication of land related disputes.

6.4.7. Role Played by Gender in Land Allocation

Makurung Land Administration System does not consider gender as a criterion in their land allocations. All applicants are treated equally, irrespective of their gender affiliation. Criteria for land allocations relates to communal membership, age of the applicant and allegiance to the land administration system, amongst others. In other communities, KwaZulu-Natal being the most popular province in terms of prevalence, female members of the community were, until recently, not legible for site allocations. Mothers could have sites allocated and registered in the names of either their sons or of their male relatives. That arrangement promoted abusive relations.

CLaRA emphasizes gender equality in the allocation of new order rights. Section 24(3)(a)(i) dictates that new order rights be allocated by the Land Administration Committee to persons, including women, the disabled and the youth in accordance with the law. Gender discrimination in land allocation will be a criminal offence and transgressors will be liable for prosecution in terms of Section 41 of CLaRA.

6.5. GPS RECORDINGS OF BOUNDARY DATA

6.5.1. Mapping Makurung with Global Positioning System (GPS)

After identification of the communal land administration boundaries on the topographic map by the Land Administration Team, GPS recordings of coordinate points marking communal land area were taken. A Geo-XT™ hand-held GPS unit was used to record points of the communal land boundary as identified by community members (Participatory mapping). Table 7 shows the data collection process followed in Participatory GPS mapping.

Table 7: Participatory GPS-Mapping Data Collection Process

POINT	MAPPING	POSITION	MARKER	DESCRIPTION	REMARKS
1	Boundary.	Makurung - sewerage road intersection.	Road intersection.	Define northern communal boundary.	Man-made feature defining boundary.
2	Boundary.	Chunies/Tudumo. River.	River (natural feature).	Top northern point of the communal land administration boundary.	Connects in a straight line with a point at the intersection and a point on the Lebowakgomo – Jane Furse road.
3-8	Recently allocated crop-field.	Close to Chunies/Tudumo river.	None.	Northern most recent allocation.	One of the two recent land allocations by the land administration team.
9-18	Recently allocated crop-field.	Close to the Makurung-Mamaolo road.	None.	Recent allocation close to the road.	The second recent land allocation made by the administration team.
19	Boundary.	Chunies/Tudumo river.	Fig tree and river.	South-eastern most point in the river.	Landmark (fig tree) significant in mapping.
20	Boundary.	Close to a Secondary School.	School.	Connecting point to point in the river and the trig. Beacon	Landmark (school) significant in mapping

POINT	MAPPING	POSITION	MARKER	DESCRIPTION	REMARKS
None	Boundary.	Hill top.	Trigonometric beacon.	Connecting point.	Use of trig. Beacon in defining boundaries display basic level mapping. Point not taken – beacon identified on topographic map.
21	Boundary.	Southern boundary.	Old church building and primary school.	Southern most point of the communal boundary.	Significance of landmarks in mapping (old church building and school).
None	Boundary.	Hill top.	Trig. Beacons number 100 and number 8.	Southern boundary of communal land.	Beacons defining boundary offers level of accuracy in mapping. Points were no necessary to capture.
22	Boundary.	Edge of Lebowakgomo – Jane Furse road, straight line with beacons.	Road and beacons.	Define south-western point of the communal land boundary.	Landmarks assisting in identifying and mapping communal land.

POINT	MAPPING	POSITION	MARKER	DESCRIPTION	REMARKS
23	Boundary.	Intersection of Lebowakgomo-Jane Furse and Hwelereng-Makurung roads.	Roads.	Connecting point.	Main road defining western boundary of communal land.
24	Boundary.	Sewerage plant.	Road.	Connecting point defining northern boundary.	Significance of features in mapping.
None	Boundary.	Edge of Lebowakgomo – Jane Furse road, straight line with road leading to the sewerage plant.	Road.	Defining north-western boundary connecting in a straight line to a point taken at the sewerage plant.	Shows the role played by features in mapping and their optimum use by local people.

6.6. ANALYSIS OF GPS RECORDINGS OF BOUNDARY DATA

6.6.1. Identification of Boundaries of Basic Communal Land Administration Area

The ability of communities to define and map their communal land administration areas is central to the successful implementation of the Communal Land Rights Act, 2004 (Act No. 11 of 2004). Knowledge of communal boundaries is crucial during the land rights enquiry process conducted by an appointed Land Rights Enquirer. Persons or communities who claim land rights on a property are expected to indicate the extent of their claim. The process would unravel land rights attached to a particular property by identifying land rights holders and would also provide an opportunity to document the boundaries of a basic Communal Land Administration System.

The Makurung Communal Land Administration Team was able to identify boundaries that represent their communal land. Natural features such as hills and a river that made up the boundary were used in the identification process. Landmarks such as trigonometric beacons, buildings and roads were identified as making up the boundaries of Makurung Village. Community's ability to use landmarks such as trigonometric beacons in mapping, despite low literacy levels among the adult population in the area, illustrates availability of basic mapping skills. Such skills are vital in support of the implementation of the Communal Land Rights Act, 2004 (Act No. 11 of 2004).

The Makurung Communal Land Administration Team also participated in the boundary recording of the recently allocated crop fields. The exercise was conducted to demonstrate the significance of continuous recordings and update of the communal resources.

6.6.2. Accuracy of GPS Recordings

In this study, attention was paid to the Horizontal Dilution of Precision (HDOP) as a 2 - dimensional accuracy indicator. The decision to consider the horizontal component (x, y) only, as opposed to the 3-dimensional accuracy indicator (x, y, and z) was informed by the fact that elevation of data was not of significance.

A Trimble Geo-XT™ hand-held GPS was used to record coordinate points marking the administration area. Differential correction procedure on the GPS recorded data collected on the 12 November 2005 failed. Upon enquiry from Trignet Mowbray the author was informed that the Trignet system for the area crushed during November and December 2005. Consequently all differential correction data for that period is lost. The nearby Trignet Base Station to the study area is Trignet Pietersburg located at latitude 23.55°, longitude 29.27° and ellipsoidal height 1307.67 metres above sea level. Attempts were made to acquire information from Trignet Thohoyandou, a base station closer to Trignet Pietersburg located at latitude 23.04°, longitude 30.23° and ellipsoidal height 630.29 metres above sea level. Trignet Thohoyandou experienced the same problem as Trignet Pietersburg.

According to vendor specifications and as confirmed by Serr, Windholz and Weber (2005) the device is capable of obtaining 3 - 5m accuracy without post-processing correction. The unavailability of differential correction data is not of grave concern since the base map (as the only available spatial reference) was a 1:50,000 topographic map whose accuracy, according to Gyamfi-Aidoo, Schwabe and Govender (2005), cannot exceed 5m.

6.6.3. Data Processing in GIS

The collected data in the form of GPS-recorded coordinates of points marking the boundary of the communal land administration were overlaid on a topographic

map. The GIS operation produced a topographic map in a Geo-referenced tagged image format depicting overlaid recordings of point coordinates marking communal land boundaries illustrated by Figure 8 (Raw Data Map).

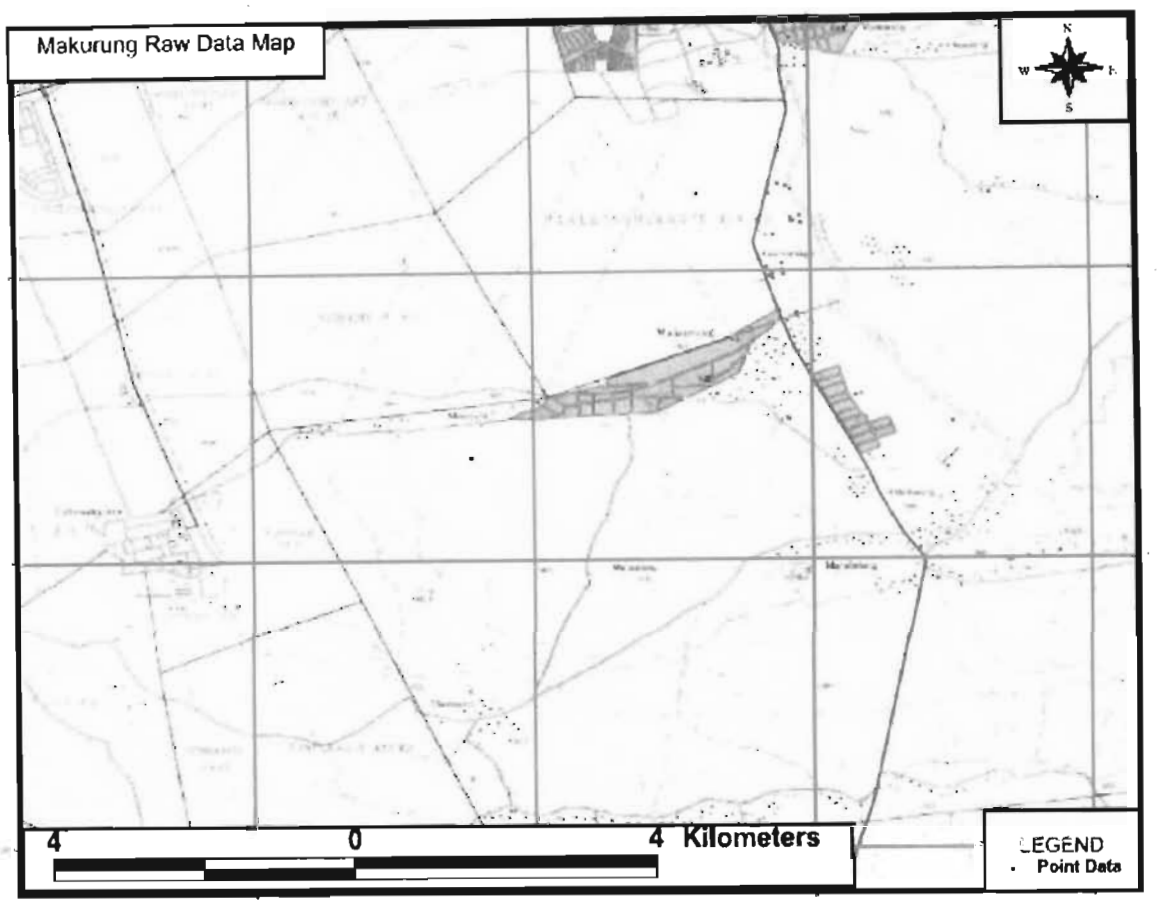


Figure 8: Makurung Raw Data Map

Through on-screen digitizing, the coordinates marking communal land boundaries were connected and a Makurung land administration boundary map was produced, represented in Figure 9. A flowchart on GPS-based mapping operations of land administration systems in a GIS, Figure 5, outlines the process followed. Below is the final product, map of Makurung village:

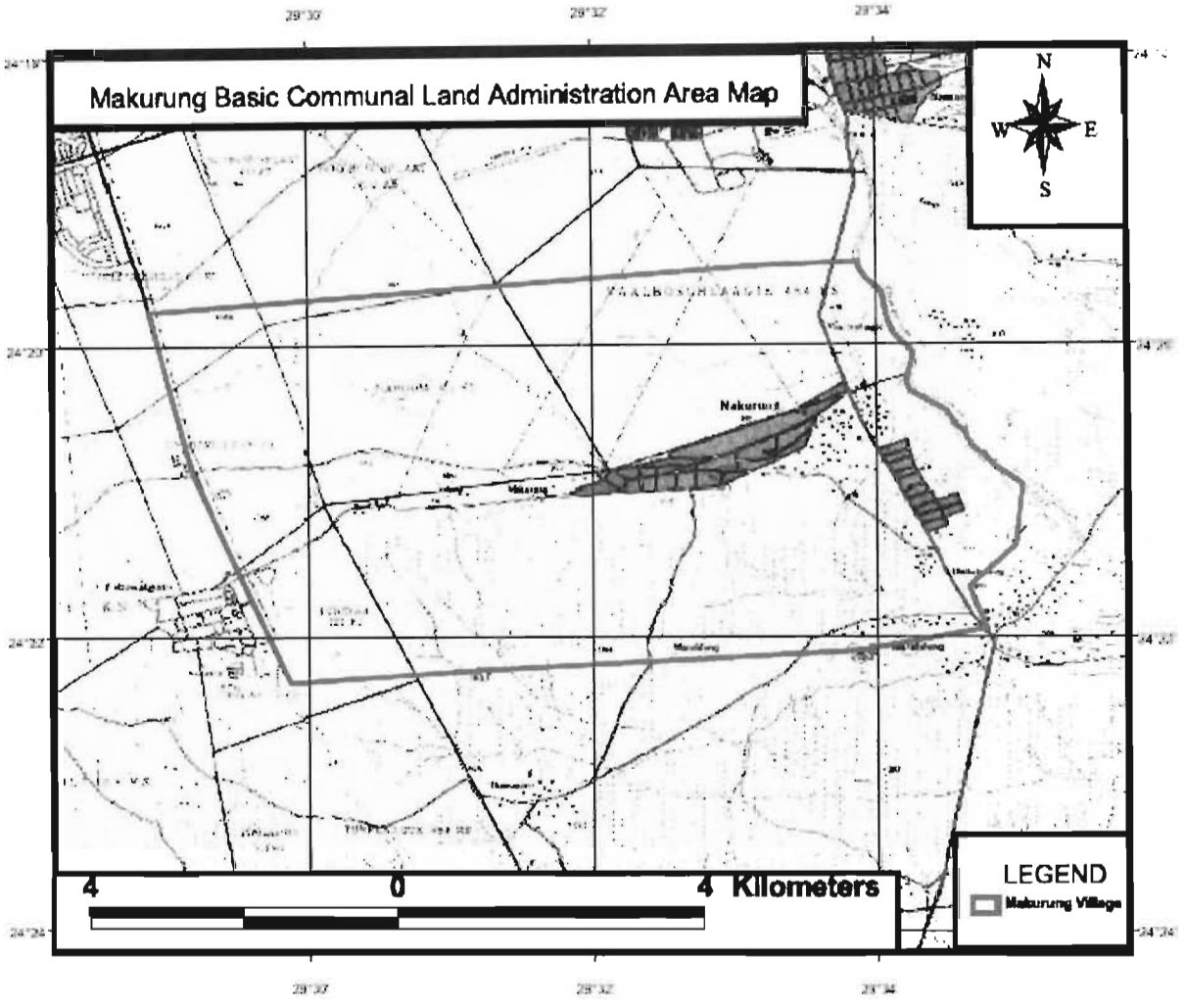


Figure 9: Final Participatory Map of Makurung Basic Communal Land Administration Area (red boundary line)

7. CONCLUSION

7.1. Introduction

This study has two objectives. The first objective is to develop a participatory GPS-based methodology for identifying and mapping communal land administration boundaries. The second is to analyze Basic Communal Land Administration Systems. The success or failure of the study may be measured by its (in) ability to meet the objectives.

7.2. Defining Boundaries and Developing Participatory GPS-Based Methodology for Identifying and Mapping Communal Land Administration Boundaries.

Makurung Land Administration Team and Ukulinga farm manager defined their communal land and farm boundaries, respectively. Their knowledge of the boundaries coupled with the ability to define extent thereof was quite impressive. Like the Asmat families in the study by Hile (2004) the Makurung Land Administration Team placed a high level of significance on mapping their boundaries. There is a contest over boundaries with the neighbouring village. The community is convinced that by mapping their boundaries they will be able to defend their territory against external threats.

Landmarks and natural features serve a significant role in defining boundaries. The boundary identification process was handled with ease, with the guidance of landmarks and natural features.

Public participation was enhanced through active participation of the Makurung Land Administration Team in defining and identifying their communal land administration boundaries. Community members' ability to identify points along the communal boundary proved vital in guiding the Researcher to record points using the GPS tool. Providing the community members with training on how to

use handheld GPS unit, on the use of computers in downloading the collected field data, interpretation and manipulation, community members would after considerable practice sessions, independently map their lands without requiring assistance of outsiders.

7.3. Understanding of Existing Land Administration Structures and Systems

Basic communal land administration structures that exist in communal areas appear in a hierarchical order as captured in Figure 6. The Induna is the head of the system and is supported in his or her administration by family, advisors, administrators (Secretariat) and the community. He or she reports to the Chief or Chieftainess through the Senior Mokgomana. The structure of land administration operates systematically in unison and is therefore referred to as a land administration system as discussed under the Structure of Tribal Land Administration.

The manner in which the system operates allows for consultations and public participation in decision-making. Land rights holders' consent is sought on matters that are likely to affect their land rights. Protocol is observed in all dealings within the system and forms part of culture, captured in community rules.

Community rules are not documented. Rules are verbally communicated in community meetings and are passed on, from one generation to the next. It is at community meetings where community rules are refined, amended and revoked guided by a common conviction that there is a need to do so. Implementation of CLaRA would assist in ensuring that community rules are documented, thereby preventing information gap between generations.

Records of registered land rights are reasonably well kept, save for the recording of inherited land rights, which require improvements. Rules for regulating

inherited rights are yet to be developed. It is believed that once such rules are developed land rights will be satisfactorily recorded.

There is a need to enhance communication between administrative institutions. Makurung Land Administration Team and Bakgaga Traditional Authority gave different versions on the responsible institution for processing the application for a site beyond the Tribal Secretary. This is a cause for concern. The administrators are expected to be conversant with the process so as to advice clients accordingly. Lack of information on the part of administrators of the process to be followed would sow confusion in applicants as they walk door to door to have their request processed.

7.4. Achievements of the Study

The Makurung Village case study provided an analysis of the existing land administration systems on communal land. Analysis on the status quo in comparison to the envisaged Land Administration Committees by CLaRA presented a broader view of the challenges ahead.

The land administration structures as exposed by the study could not be adopted, in current form, into the CLaRA Land Administration Committees because their make up is not in line with what CLaRA advocates.

The Ukulinga University Research Farm case study provided a better understanding of the principles and operation of high precision handheld GPS and also established the accuracy levels obtainable in surveys. A Participatory GPS-based methodology for identifying and mapping communal land administration boundaries was developed. The efficacy of GPS is demonstrated in the results obtained from a comparative study of coordinates of the trigonometric beacon provided by the Surveyor General with those captured by the Trimble Geo-XT™ GPS receiver.

Communities, particularly those in land administration, know their communal land boundaries. They have mind maps of the areas and are able to identify boundaries with ease. Natural features and landmarks, where applicable, are reliable markers in identifying and mapping communal boundaries.

A Trimble Geo-XT™ GPS receiver was used to record boundary marker points. The mapping exercise carried out on Ukulinga farm achieved sub-metre post-processing differential correction accuracy as declared by the manufacturer. The mapping process followed in the two case studies was also proved to be effective and efficient. Moreover, it is believed that sub-metre accuracy levels would have been achieved for the Makurung case study had post-processing differential correction data been available.

Research questions were answered satisfactorily. Clarity provided by the collected primary data on the existing land administration systems and how boundaries of those administration systems are defined proved insightful. In fact, communities have the knowledge and skills that enable them to identify their land area. The research objectives were also achieved. As indicated earlier an analysis of basic Communal Land Administration Systems was provided and a participatory GPS-based methodology for identifying and mapping boundaries is documented under the research methodology.

8. RECOMMENDATIONS

Based on the findings of this study and the foregoing conclusion it is recommended that the methodology used in this study be considered in the land rights enquiry process in the implementation of the Communal Land Rights Act, 2004 (Act No.11 of 2004). It is also recommended that community members be offered capacity building and empowerment training in using Participatory GPS and GIS. Such training opportunities, if provided, would improve the local people's ability to map their land resources. It is further recommended that other studies be commissioned to look at Communal Land Administration Systems in other regions to establish local variations that may be considered in the possible implementation of the method.

REFERENCES

Abeto, R., Calilung, Z., Talubo, J.P. and Cumatang, B. (2004) [Online] *Community Mapping in the Philippines: A Case Study on the Ancestral Domain Claim of the Higa-onons in Impasug-ong, Bukidnon.* Paper presented at the Regional Community Mapping Network Workshop November 8-10, 2004, Diliman, Quezon City, Philippines.
Available:http://www.iapad.org/publications/ppgis/community_mapping_in_the_phillipines.pdf
Accessed: July 2005

Alcock R and Hornby D. (2004) Traditional Land Matters: A look into land administration in tribal areas in KwaZulu-Natal, Legal Entity Assessment Project, Durban, South Africa

Alspach, A.J. (1999) [Online] *Integration of Geographic Information Systems (GIS) in Regional Participatory Development Projects.*
Available:http://www.socsci.umn.edu/~bongman/gisoc99/new/alspach.htm.
Accessed: July 2005

Anderson, P.S. (2000) [Online] *Mapping Land Rights in Mozambique*
Available: http:lilt.ilstu.edu/psanders/geo/MOZAMART1/htm
Accessed: July 2005

Augustinus, C. (2003) Comparative analysis of land administration systems: African review, Draft 1.

Baral, H., Petheram, R.J. and Liffmann, P. (2004) [Online] *Agricultural Research and Extension Network. Newsletter No. 50.*
Available:http://www.iapad.org./publications/ppgis/agren_newsletter_50.pdf.
Accessed: July 2005

Bujang, M (2004) [Online] *A Community Initiative: Mapping Dayak's Customary Lands in Sarawak, Diliman, Quezon City, Philippines.*
Available:http://www.iapad.org/publications/ppgis/brimas_Malaysia.pdf
Accessed: November 2005

Buschermohle, M.J. (2005) [Online] *Connecting your GPS receiver to ArcPad.* Biosystems Engineering and Environmental Science, University of Tennessee Institute of Agriculture.
Available:http://bioengr.ag.utk.edu/personnel/buschermohleMichael/docs/BESS_103.pdf Accessed: December 2005.

Charrois, D. (1999) [Online] *Study of the accuracy of averaged non-differential GPS measurements.*
Available: http://www.syz.com/gps/gpsaveraging.html.
Accessed: December 2005.

Chivers, M. (2003) [Online] *Differential GPS Explained*, ArcUser Online
Available: http://www.esri.com/news/arcuser/0103/differential1of2.html.
Accessed: December 2005

Claasens, A. (2001) *It is not easy to challenge a chief: Lessons from Rakgwadi,* School of Government. University of the Western Cape, Cape Town

Communal Land Rights Act, 2004 *(Act 11 of 2004),* Cape Town, Republic of South Africa

Corbley K. (2005) *Field of beams: Communities are using a new generation of portable GPS units to expand their GIS mapping,* Winchester, USA, PRIMEDIA Business Magazines and Media, Inc.

Corvallis Microtechnology Inc. (2000) [Online] *Introduction to the Global Positioning System for GIS and Traverse*
Available: http://www.cmtinc.com/gpsbook/index.htm
Accessed: November 2006

Cousins, B. (1999) *At the crossroads: Land and agrarian reform in South Africa into the 21st century*. Paper from a conference held at Alpha Training Centre, Broederstroom, Pretoria, 26-28 July 1999

Cousins, B. (2002) *Reforming Communal Land Tenure in South Africa – Why land titling is not the answer: Critical comments on the Communal Land Rights Act*. Cape Town, South Africa

Crosnier, Y. (2000) [Online] *Spot Helps Resolve Land Tenure Issues*, Sezanne, France
Available: http://ceos.cnes.fr:8100/cdrom-00b/ceos1/casestud/mali/mali.htm
Accessed: August 2005

Dale, P and McLaughlin J. (1999) *Land Administration*. Oxford University Press Inc., New York, US

Dana, P.H. (1999) *Global Positioning Systems (GPS) and Geographic Information System (GIS) a "hands-on" approach*, Department of Geography, University of Texas, Austin

DePriest, D. (2006) [Online] *Differential GPS*
Available: http://www.gpsinformation.org/dale/dgps.htm Accessed: July 2006

GPS Primer. (2003) [Online] *A student guide to the Global Positioning System*, The Aerospace Corporation, USA
Available: (http://www.aero.org) Accessed: July 2006

Gyamfi-Aidoo, J. Schwabe, C. and Govender, S. (2005) *Determination of the fundamental geospatial data for Africa through a user needs analysis.* A synthesis report for the Chief Directorate: Surveying and Mapping, South Africa.

Harris, T and Weiner, D. (2004) [Online] *Community-Integrated GIS for Land Reform in Mpumalanga Province, South Africa*
Available: http://www.ncgia.ucsb.edu/varenius/ppgis/papers/harris.html
Accessed: April 2005

Iivula-Ithana, P. (2004). Chapter 3: Land Tenure in Southern Africa; From Colonialism to Modern Tenure Systems. In: Roth, M., Nxasana, V., Sibanda, S. and Yates T. (*eds*) *National Land Tenure Conference – Finding Solutions, Securing Rights : Papers and perspectives from the National Land Tenure Conference, ICC, Durban, South Africa, Department of Land Affairs*, Lexis Nexis Butterworths, Pretoria, South Africa.

Irrigation Training and Research Centre. (1998) *Evaluation of techniques to determine landscape areas.* BioResource and Agricultural Engineering Department, California Polytechnic State University, San Luis Obispo, CA 93407.

Keym, P. (2001) *An Application of a Choice Heuristic Algorithm for Mapping Land Resource Allocation Problems Involving Multiple Parties and Conflicting Interests, Transactions in GIS*, Vol.5 (2), pp.111-129

Keym, P. (2004) *Of Intractable Conflicts and Participatory GIS Applications: The Search for Consensus amidst Competing Claims and Institutional Demands,* Annals of the Association of American Geographers, Vol. 94, (1), pp.37-58

Kurniawan, I. and Hanafi, I. (2004) *Community Mapping, Natural Resources and Indigenous People Movement in Indonesia,* Diliman, Quezon City, Philippines

Lasimbang, A. (2004) [Online] *Community Mapping in Malaysia: The use of Community Maps in Resources Management and Protecting Rights over Indigenous Peoples' Territory.* Paper presented at the Regional Community Mapping Network Workshop November 8-10, 2004, Diliman, Quezon City, Philippines.
Available: http://www.iapad.org/publications/ppgis/pacos.pdf Accessed: July 2005

Leisz, S., Robles, A. and Gage, J. (1995) [Online] *Land and Natural Resource Tenure and Security in Madagascar.*
Available: http://www.ies.wisc.edu/ltc/madagas.html Accessed: July 2005

Luo Z., Ning, J. Chen, Y. and Yang, Z. (2005) *High Precision Geoid Models HKGEOID-2000 for Hong Kong and SZGEOID – 2000 for Shenzhen, China,* Taylor and Francis Inc.

Marongwe, N. (2003) *Land and Resources Rights in Southern Africa, Paper presented at the Pan-African Programme on Land Resources Rights (PAPLRR) Workshop*, 5-7 May 2003, Cape Town, South Africa

Martin, E. (1997) [Online] *Visualising common lands: A framework component of GIS use in other cultures*
Available: http://students.washington.edu/~ewmartin/papers/viscom.htm
Accessed: May 2005

Mbile, P. and DeGrande, A. (2003) [Online] *Integrating Participatory Resource Mapping and Geographic Information Systems in Forest Conservation and Natural Resource Management in Cameroon: A methodological guide.* The Electronic Journal on Information Systems in Developing Countries
Available: http:www.ejisdc.org 14(2): 1-11. Accessed: July 2005

Mbile, P., DeGrande, A., and Okon, D. (2003) [Online] *Integrating Participatory Resource Mapping and Geographic Information Systems in Forest Conservation and Natural Resources Management in Cameroon: A Methodological Guide.* The Electronic Journal on Information Systems in Developing Countries.
Available: http://www.ejisdc.org Accessed: August 2005

McConchie, J.A. and McKinnon, J.M. (2002) *Using GIS to Produce Community-Based Maps to Promote Collaborative Natural Resource Management.* Asean Biodiversity. January – March 2002. Pp.27-34

Minang, P.A. (2003) *Assessing Participatory Geographic Information System for Community Forestry Planning in Cameroon: A local Governance Perspective.* Unpublished MSc thesis. Enschede, ITC: 104.

Mohamed, M. and Ventura, S. (2000) *Use of Geomatics for Mapping and Documenting Indigenous Tenure Systems,* Society and Natural Resources, Vol. 13 pp.223-236

Obala, L. and Kinyungu, N. (2002) [Online] *Current Changes in Customary/Traditional Land Delivery Systems in Sub Saharan African Cities - Case Study of Nairobi.* University of Nairobi, Kenya
Available:http://www.ucl.ac.uk/dpu/research/housing/Kenyacasev3%202%20.pdf.
Accessed: July 2005

Poole, P. (1995) *Indigenous Peoples, Mapping and Biodiversity Conservation: An analysis of Current Activities for Applying Geomatics Technologies.* Local Earth Observation Project

Poole, P. (2003) *Cultural Mapping and Indigenous Peoples.* UNESCO

Rambaldi, G., McCall, M., Weiner, D., Mbile, P and Kyem, P. (2004) [Online] *Participatory GIS (PGIS).*
Available: http://www.pafid.org/ Accessed: August 2005

Regulation Gazette No.5988 (1997) Vol. 386, 29 August 1997, No. 18229, Government Notices Department of Land Affairs No. R. 1130, Republic of South Africa. Pretoria

Rihoy, E. (1998) *Natural Resource Tenure in Southern Africa: Exploring options and opportunities, SADC Natural Resource Management Project*, Johannesburg, South Africa

Rihoy, E., Jones, B., Anztey, S. and Rolfes, M.T. (1999) *Tenure in transition: A stakeholders guide to natural resource tenure in Southern Africa.* USAID

Roth, M., Nxasana, V., Sibanda, S. and Yates T. (2004) *National Land Tenure Conference – Finding Solutions, Securing Rights : Papers and perspectives from the National Land Tenure Conference,* ICC, Durban, South Africa, Department of Land Affairs, Lexis Nexis Butterworths, Pretoria, South Africa

Serr, K., Windholz, T and Weber, K. (2005) [Online] Comparing GPS receivers: A field study. GIS TReC, ISU.
Available:http://giscenter.isu.edu/research/techpg/nasa_weeds/to_pdf/gps_accuracy_precision.pdf Accessed: December 2005

Sibanda, S.M.D. (1999) [Online] *Land Tenure, Investment And Economic Development In Communal Areas: Briefing Paper For The Cabinet Investment Cluster.*
Available:http://land.pwv.gov.za/tenurereform/new_tenurereform/Unpublished/Unpublished_works/Customa1.doc Accessed: June 2005

Sibanda, S.M.D. (2006) *The birth of a new order and unitary land administration system in communal areas of South Africa*, Walter Sisulu University Law Journal 2006, Law School of Walter Sisulu University, Mthatha, South Africa.

Sirait, M., Prasodjo, S., Podger, N., Flavelle, A. and Fox, J. [Online] *Mapping Customary Land in East Kalimantan Indonesia: A Tool for Forest Management.*
Available: http://www2.eastwestcenter.org/environment/fox/kali.html
Accessed: April 2005

Traditional Leadership and Governance Framework Amendment Act, 2003 *(Act 41 of 2003) Vol. 462* Republic of South Africa, Cape Town

Trimble GPS Tutorial, All About GPS. [Online]
Available: http://www.trimble.com/gps/index.shtml
Accessed: April 2005

US Army Corps of Engineers. (2003) NAVSTAR Global Positioning System Surveying. Engineer Manual EM 1110-1-1003. Washington DC 20314-1000

Van Wyk, J. (1999) *Planning Law: Principles and Procedures of Land-use Management.* Juta and Co, Ltd, Kenwyn, South Africa

Verplanke, J.J. and McCall, M.K. (2003) [Online] *Boundary dispute settlement using Mobile GIS*
Available: http://gis.esri.com/library/userconf/proc03/p0468.pdf
Accessed: August 2005

White Paper on South African Land Policy, 1997, Republic of South Africa, Cape Town, South Africa

Weiner, D., Harris, T.M. and Burkhart, P.K. (2003) [Online] *Local Knowledge, Multiple Realities, and the Production of Geographic Information: South Africa and West Virginia Case Studies.*
Available: http://www.geo.wvu.edu/i19/papers/weiner3.html
Accessed: August 2005

Wikipedia, The Free Encyclopedia [Online]
Available: http://en.wikipedia.org/wiki/Global_Positioning_System
Accessed: June 2005

Wobner, M. (2005) [Online] Sources of Errors in GPS.
Available: http://www.kowoma.de/en/gps/errors.htm. Accessed: December 2005.

Wormley, S.J. (2005) [Online] *GPS Errors and Estimating Your Receiver's Accuracy*
Available: http://edu-observatory.org/gps/gps_accuracy.html
Accessed: July 2005

Yoshimura, T., Nose, M. and Sakai, T. (1995) *High-end GPS vs Low-end GPS: Comparing GPS positional Accuracy in the Forest Environment,* Kyoto University, Japan

Appendix: 1

Interview questions designed for Makurung communal land administration

1. Who is responsible for administration of communal land?
2. What are the procedures followed in acquiring a site?
3. What is the criterion used in considering applications for sites?
4. Is gender of the applicant important in screening applications for sites?
5. How the communal land administration does operate?
6. What do you regard as challenges facing Makurung communal land administration?
7. Are the land rights recorded? If yes, how?
8. What are the plans for dealing with the challenges raised?
9. How will you define the boundaries of your communal land?
10. Can you identify the boundaries from the topographic map?

Appendix: 2

Interview questions designed for Bakgaga Traditional Authority

1. How will you explain the system of communal land administration of Bakgaga?
2. How the land administration system does operate?
3. What is the land allocation procedure?
4. Do the existing structures ensure community representation and participation? If yes, how?

Appendix: 3

GPS position attributes as recorded by the operating TerraSync™ software during participatory mapping of the Makurung Land Administration boundary.

Point_ID	Boundary Marker Description	Max_PDOP	Max_HDOP	No. of logs averaged	Latitude	Longitude	GPS_Height
9	Induna's homestead	2.9	1.2	30	-24.345957286	29.562204291	930.673
580	Mid stream dwnstrm sewage	3.4	1.7	12	-24.327561064	29.564499374	941.214
817	Road jntn1	3.7	1.7	22	-24.324192328	29.561724086	943.438
966	sand excv	2.7	1.0	10	-24.323318964	29.562858342	942.207
1165	From jntn1 to river pnt1	3.2	1.2	12	-24.323434006	29.563850146	946.478
1282	River edge bndry pnt1	4.8	1.7	25	-24.323832192	29.564409950	944.670
1633	fied allctn pnt1	3.3	1.5	21	-24.327044534	29.564361585	942.820
1691	field allctn pnt2	2.8	1.3	21	-24.326873072	29.565457012	945.259
1757	field allctn pnt3	4.5	2.8	21	-24.327639568	29.565568341	944.403
1801	field allctn4	8.0	2.9	22	-24.327540108	29.564665078	940.205
1862	field allctn pnt5	6.7	2.6	23	-24.327438701	29.564431633	935.599
1940	field allctn2 pnt1	7.9	2.4	21	-24.333279987	29.563591359	931.188
1972	field allctn2 pnt2	4.2	1.9	22	-24.333362285	29.563320650	932.163
2003	field allctn2 pnt3	7.1	2.2	21	-24.333699312	29.563436183	931.098
2061	field allctn2 pnt4	1.9	1.0	23	-24.334077224	29.562275405	935.316
2095	field allctn2 pnt5	4.0	1.9	24	-24.333763157	29.562137775	932.903
2130	field allctn2 pnt6	4.0	1.8	20	-24.333872005	29.561812522	935.581
2179	field allctn22 pnt7	1.9	1.1	20	-24.332901171	29.561481273	935.785
2250	field allctn2 pnt7	2.0	1.1	28	-24.332387022	29.563267027	934.808
2879	River bnd pnt2	4.3	2.1	21	-24.350794551	29.583534010	908.353
3359	Bnd pnt south	4.7	2.1	34	-24.356125123	29.582893568	906.835
3588	Bnd pnt schl	3.0	1.8	22	-24.365560609	29.579500704	901.424
4053	chckn frm	2.6	1.6	21	-24.354889249	29.525939759	945.123
4463	Bnd pnt tar rd overlkng bcn	7.6	4.7	22	-24.371838472	29.497937505	965.629
4604	Bnd pnt tar rd jnctn	2.9	2.3	26	-24.347890125	29.486566494	991.640
5915	Sewage plnt pnt	4.2	3.4	25	-24.324230980	29.553160775	947.670

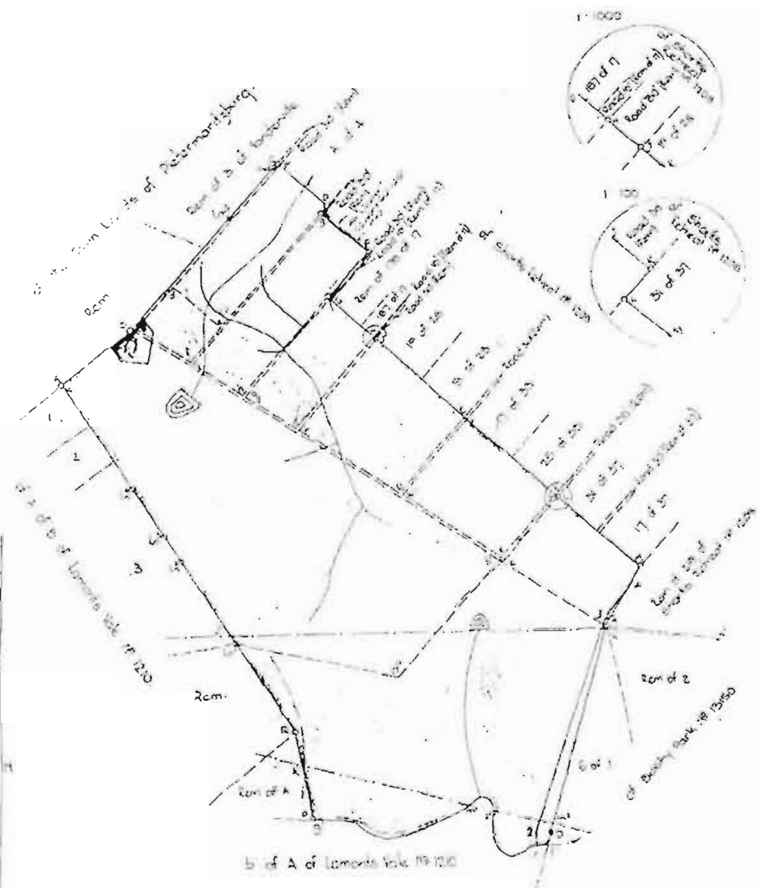
System Lo 31°

SIDES ENGLISH FEET		ANGLES OF DIRECTION				CO-ORDINATES Y	X
		Constants				+ 30,000 00	+ 10760,000 00
AB	541 4	250	21	50	A	+ 16501	+ 10021 5
BC	2580 6	220	05	00	B	+ 10000 1	+ 5920 6
CD	605 2	310	45	10	C	+ 5581 5	- 0125 5
DE	110 0	40	5	10	D	+ 0002 0	- 6000 0
EF	552 5	310	5	20	E	+ 0502 6	- 6664 2
FG	605 2	40	40	0	F	+ 6405 6	+ 5064 2
GH	862 6	310	55	10	G	+ 6005 2	+ 6581 0
HJ	29 5	300	24	20	H	+ 6045 9	+ 10011 3
JK	2581 0	310	50	50	J	+ 6020 6	+ 10058 5
KL	2 5	40	17	10	K	+ 6507 4	+ 11714 5
LM	122 5	310	0	10	L	+ 6585 5	[illegible]
MN	750 0	27	20	40	M	+ 6651 5	+ 12440 6
NO	2550 8	14	05	0	N	+ 6072 0	- 15058 1
OP	2515 8	55	35	50	O	+ 9470 8	+ 10047 5
PQ	550 4	166	17	10	P	+ 6886 0	+ 10190 2
QA	4405 2	146	58	50	Q	+ 5182 7	+ 14204 4
Ar		345	17	10			
Gt		14	55	0			

S. G. No. 3794/53

Approved

R. Fischer
Surveyor General.
- 4 -12- 1953



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1. The figure b d e f representing Sub 'Spring' of the farm Shortts Retreat No 1206 vide diagram Sub Vol 62 fol 70 relating to Deed of Transfer No 1860/1859
2. The figure d f' a e representing Remainder of a of the farm Shortts Retreat No 1206 vide diagram Sub Vol 15 fol 48 relating to Deed of Transfer No 336/1862
3. The figure j g f h representing Sub 5 of the farm Shortts Retreat No 1206 vide diagram Sub Vol 15 fol 45 relating to Deed of Transfer No 447/1861
4. The figure g' h n representing Sub 50 of the farm Shortts Retreat No 1206 vide diagram Sub Vol 15 fol 68 relating to Deed of Transfer No 446/1861.
5. The figure J L u r representing Sub 25 of the farm Shortts Retreat No 1206 vide diagram Sub Vol 20 fol 67 relating to Deed of Transfer No 501/1864.
6. The figure v y x w representing Sub 50A of the farm Shortts Retreat No 1206 vide diagram Sub Vol 20 fol 70 relating to Deed of Transfer No 501/1864
7. The figure L M N z representing Sub 51 of the farm Shortts Retreat No 1206 vide diagram Sub Vol 41 fol 125 relating to Deed of Transfer No 563/1877
8. The figure Ln' d' b' H f' middle of stream g' Q representing Remainder of a of A S I N(?) of the farm Lamonts Vale No 1210 vide diagram Sub Vol 34 fol 19 relating to Deed of Transfer No 1011/1871
9. The figure A B d' d' Ln' representing Sub ? of ? of the farm Lamonts Vale No 1210 vide diagram Sub Vol 225 fol 31 relating to Deed of Transfer No 6371/1904.
10. The figure B b' f c g j h u l y n H J r u t ... v K z representing Sub 262 of the farm Shortts Retreat No 1206 vide diagram S.G. No 410/56 relating to Deed of Transfer No 3971/1953

Beacons

A E F G K L N P Q	:	¾" round Iron Pegs in concrete under stone cairns (Q is 7' N of railmetal corner post)
B	:	Freestone beacon with hole in top
C	:	1¼" Round Iron Peg under stone cairn & in concrete with ¾" round iron peg in concrete) ad to B (C is in bottom of donga)
D	:	½" in concrete
H J	:	¾" Pegs
M	:	¾" hole in concrete 6' E of rail metal corner post
H	:	Rail metal corner post in concrete W ... (¾" Round Iron Pegs) 5' to O and ...
Ln'	:	¾" Round Iron Peg under stone cairn and in concrete (Line beacon)
Ln[4] Ln[2] Ln[3]	:	¾" Pegs cairns (Line beacons)
Ln[5]	:	¾" ... cairn and in concrete (Line beacon)

SCALE 1:15000

BEACONS B REPLACED/RELOCATED	VIDE S.R. NO. 635/576

ESTABLISHED Beacons	Boundaries	Ref No. S.R. No.
D	C - D	15/1928
		133/1957

The figure A B C D E F G H J K L M N f' middle of stream g' Q

represents 317 4068 Acres of land being

the farm UKULINGA No 14066

and comprises the properties quoted above

situate in the County of Pietermaritzburg Province of Natal.

Surveyed in March 1945, March 1945, January 1947, March and May 1948, May and June 1953, by me

D. G. Laidlaw
Land Surveyor.

The line j'H' represents the middle line of an Electric Power Transmission Line Servitude vide diagram Sub Vol 621 folio 22 and 0/5 S.G. ...

The lines K'm' and Z'm[2] represents the middle lines of an Electric Power Transmission Line Servitude vide diagram S.G. No ... 6137/53

Reg. Dwg. FT

This diagram relates to C.N.T.C. No. 3 ... / 5... Registrar of Deeds	The original diagrams are as quoted above ~~relating to Deed of~~	File No. 6861 Survey Records 759/53 Compilation FT6G, FT5H. Degree Sheet 2930 58 ~~FT5D~~ Tracing General Plan

COMP FT6DB5C

T.A. ... M.S. 6193-1-48

SG Diagram of Ukulinga University Research Farm

Appendix: 4