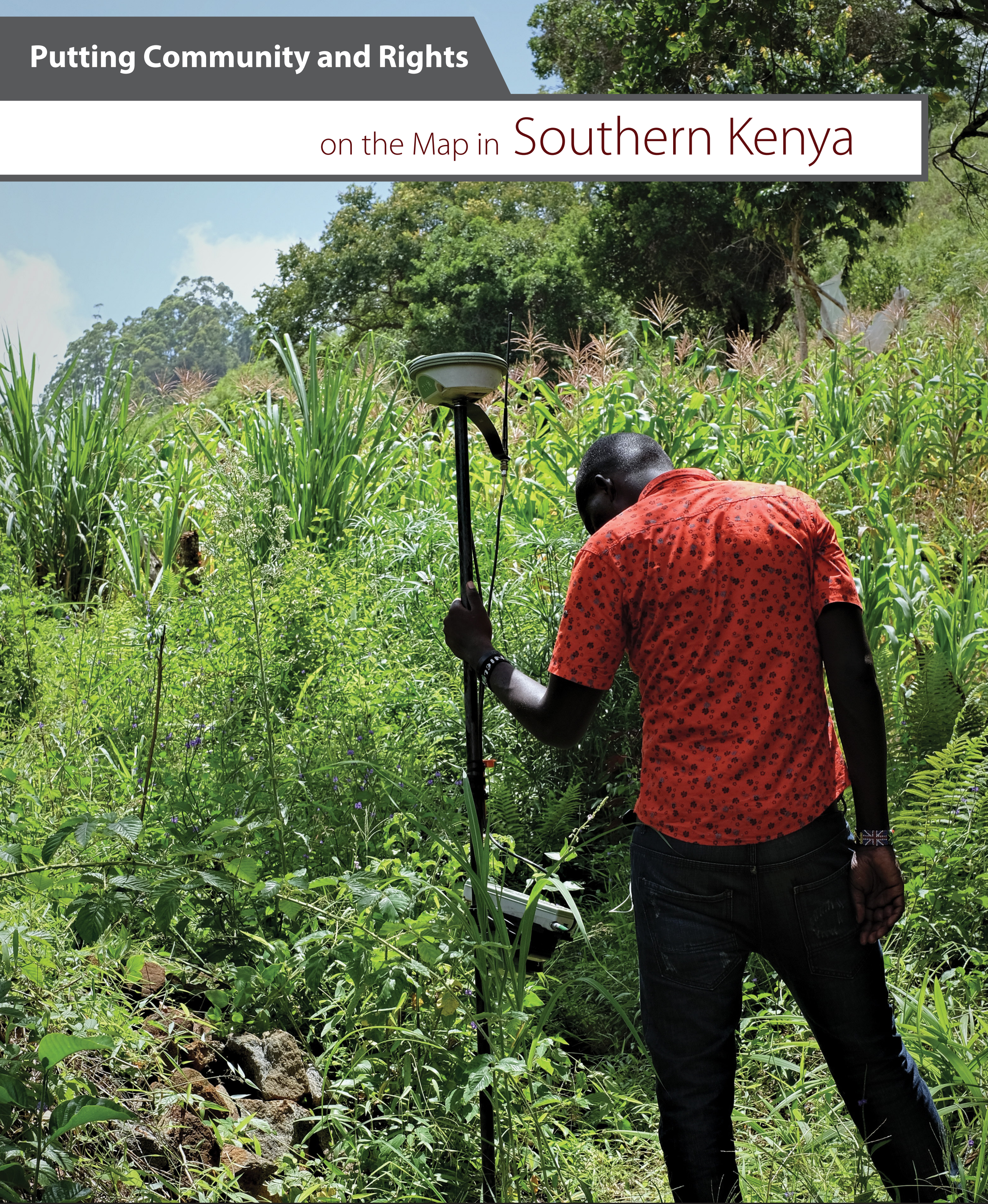
Putting Community and Rights on the Map in Southern Kenya



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Acknowledgements

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SPATIAL COLLECTIVE

OMIDYAR NETWORK

About
Spatial Collective

Spatial Collective is a Kenyan company specializing in community mapping. Spatial Collective supports communities and organizations in adopting available technologies to collect, store, analyze and own data on issues that are important to them and then help them use that information to improve development outcomes. The company specializes in remote and difficult to access areas, work on topics such as community land rights, crime and insecurity, and access to services in informal settlements. Since 2012, the team has delivered projects in countries across Africa and worked with a range of the leading organizations in international development.

Putting Community and Rights on the Map in Southern Kenya

Executive Summary

The Community Lands Act of Kenya – passed in September 2016 – provides for the recognition, protection, and registration of community land rights. One of the requirements to registering community land is for communities to agree on and identify the community resources and boundaries to determine which entity deserves recognition for ownership. For this reason, there is an urgent need to build the most affordable and sustainable systems for mapping community lands.

We believe that through affordable and ubiquitous technologies, coupled with awareness raising and training, local communities can understand their land rights and contribute to proper land mapping in rural and remote areas of Kenya. While Kenya has existing legislature and controlling bodies to enact land laws, many local communities remain unaware of their rights and the processes to claim and register land. This leaves a large part of the country unmapped and communities ripe for dispute and confrontation.

A wide selection of geospatial technologies exist to accurately survey the land, however, many of these are expensive, require very specialized skills to operate or facilitate and, in some cases, muster a hostile reaction from the communities due to its unfamiliarity of use. In our research we looked at off-the-shelf, easy to use, hand-held mobile and GPS units and their potential in communities' participation in land demarcation. We chose these tools because their learning curve is less steep compared to some other technologies for land mapping. These tools are ubiquitous and habitually used in many aspects of life in Kenya, such as communication, entertainment, access to information, Internet, and mobile banking. We were interested to see whether these tools can be used in property rights mapping to reach the accuracy and attribution threshold required by the state for land demarcation.

To do this, Spatial Collective implemented a three step approach. First, we examined the process of land demarcation for new grants and for the subdivision of land. We were specifically interested in the accuracy and attribution of spatial data required by professional surveyors and government offices for demarcation of land. Second, we tested a series of affordable mobile and GPS tools in varying environments to see whether they can achieve these thresholds. And third, by replicating the work of a professional surveyor, we assessed whether communities can lead the process of demarcation of their own lands.

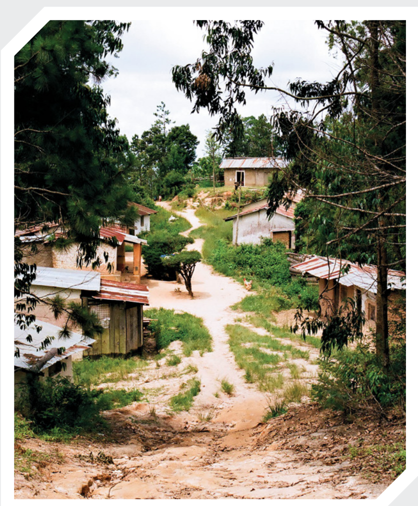
We found that environmental factors greatly affect the nature of measurements of different terrains. Most of the latest mobile phones can only reach the accuracy standards required for mapping general boundaries, which is three meters or lower. This is the standard required for mapping parcels and community land in rural areas in Kenya. These tools cannot be used for the capture of fixed boundaries which require two to three centimeter accuracies.

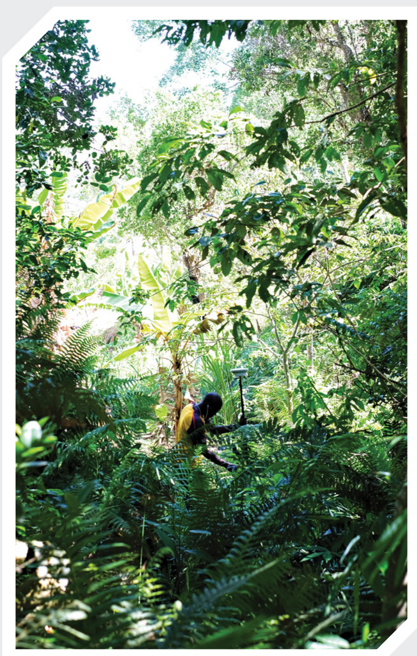
Furthermore, we found that a pairing of mobile and GPS dependencies may provide the most optimal and cost-effective measurements in the face of environmental and terrain challenges and limited network connectivity.

Working with communities and a professional surveyor, we find that communities can lead the process of land demarcation and can replicate the work of a professional surveyor both in terms of accuracies and attribution required in rural areas. Smart phones can store the necessary attribute data from the field in a digital format, fulfilling the requirements to document people, land and associated rights. Training is relatively simple and most processes repeatable to a satisfactory standard, and the possibility of having units available at sub-county level that can be rented out to communities makes it cost effective and affordable.

Most rural parcels are currently registered only through pen and paper and sometimes by a measuring tape. The information is then stored in paper format at the County offices, making it susceptible for manipulation, corruption and loss. The ubiquitous mobile phones and GPS units provide an excellent alternative to the system that is currently used.

We believe our research can empower local people to rightfully claim land and thus eradicate future land disputes and conflicts amongst them. We also believe there are opportunities for policymakers, lawmakers, technical experts, and administrators to use these insights to influence and shape their land rights agendas, as well as support efforts to better include local people and accurately map boundaries in Kenya.





Introduction

Previous Efforts

With support from Omidyar Network and Oxfam, and pending the passing of the Community Lands Bill in 2016, Spatial Collective provided technical assistance to Namati and Kenya Land Alliance on mapping community lands in two communities in Tana River County (Chara and Handaraku).

Spatial Collective used a mixed-methods approach to map these lands which included:

- Training of staff on appropriate selection of tools and subsequent data collection;
- Participatory map drawing with communities to determine the size, locations of boundary points and land use in the area;
- GPS data collection to capture locations of community land boundaries and land features;
- Post-processing of data including digitization of satellite imagery;
- Producing two maps of these community lands.

There was wide consensus amongst partners and government officials that mapping of community land is a technically and politically sensitive undertaking. To scale up the documentation of community lands, and to make the process more transparent, it was evident that more focus was needed on identifying low-cost and accessible technology (mobile, GPS, GIS) and on strengthening land administration systems managing spatial data.

Spatial Collective's work scales up these efforts in the Coastal Region of Kenya.

The Need for Inclusive Community - and Data-centered Land Registration Within Standards and Legal Thresholds

In countries across Africa, many people do not have access to formal land registration. Individual and shared property rights have not been properly documented or acknowledged.

Lack of documentary evidence of customary property rights leaves individuals, households and communities at a disadvantage. Lack of customary land rights have undermined the ability of individuals, households and communities to protect their traditional access to land for agriculture, environmental conservation and mineral rights. Government and private companies have been able to evict communities or make claims and prospect in areas where rights have only been expressed by oral tradition[1]. Even within communities, undocumented transfers of land have caused confusion. Where a title deed may exist, the deed has not been updated by any subdivisions or bequests and may refer to a deceased party as owner. Land may be grabbed or obtained without challenge, traditional rights of access, usage and sale values are undermined. Moreover, landowners have no proof of ownership which could allow them to borrow credit.

Getting legal evidence of rights to property has been a lengthy and expensive process which requires precise measurements of boundaries and rights of access or easements of land that can usually only be done by trained surveyors. Also the types of customary rights which have been declared by communities may not fit the formal legal definition of land title rights.

The current act (2016) gives communities both the right and the outline of a mechanism by which customary land can be legally recognised for the first time in Kenya. As yet, the detail of the registration process is unclear and requisite forms have not been disseminated. This means that registration is currently conducted to the standards required by formal titling. The whole process is limiting and communities are confused as to how to go about the registration process.

Key bottlenecks are assumed to be:

1. Lack of affordable tools to empower people to obtain rights to their land.
2. Local communities have no access to information.
3. Local communities are not able to value their land.
4. The registration process is unclear or unknown to the communities.
5. The relationships between Kenyan national, community and individuals in terms of property rights is difficult for communities to comprehend.
6. Antiquated procedures sustained through inertia in the titling process and an inability to explore, let alone adopt new technologies to replace old methods.
7. Technical tools used to capture vital info on mapping are often too expensive, difficult to operate, rely solely on connectivity, and require extensive training/maintenance and complex processing solutions. In some cases the skills needed to record information accurately often built up over many years of experience including formal qualifications.

[1] *Land Rights Now, 2016.*

So while there might be a perception by the national government that customary titling can move forward, communities struggle to work out a cost-effective path to documented rights. With titling, people can buy and sell land more easily, protect and manage the land more effectively, and conserve the resources on and under that land.

The current limited network of both government and private surveyors would be overwhelmed if all communities rushed to document their land at this time. Professional surveyor's fees needed at demarcation and titling stages of the process would be prohibitive for most communities, let alone individual owners within those communities.

This research applied new technologies to the data capture element of registration in order to test whether affordable tools for documentation of land exist, whether these tools can reach the accuracy standards required by the state, and whether communities can replicate the work of a professional surveyor. To do this, the research looked into the land demarcation process, determined whether new technologies were of quality and met national standards, and gauged the most cost-effective tools which are widely accessible to local communities.

Methodology

The idea of communities demarcating their own land is predicated on a series of assumptions:

1. That cheap and widely available tools that can be used for land demarcation exist.
2. That these tools can reach the demarcation threshold required be the Kenyan government in terms of accuracy and attribution.
3. That the communities, using these tools, can replicate the work of a professional surveyor.

To test these assumptions, we conducted a series of experiments in Taita Hills, Taita Taveta County:

1. We examined the process of demarcating land both for new grants and for subdivision of land. Specifically, we focused on the accuracy and attribution of spatial data required by the professional surveyor and government offices.
2. We tested a series of affordable and ubiquitous technologies for capture and demarcation of land to see whether they achieve the thresholds required. We tested these tools under varying environmental conditions to see how they affect the measurements.
3. Finally, we assessed whether communities can replicate the demarcation of land by the professional surveyor using these tools.

The Affordable Tools for Demarcation of Land are Widely Available

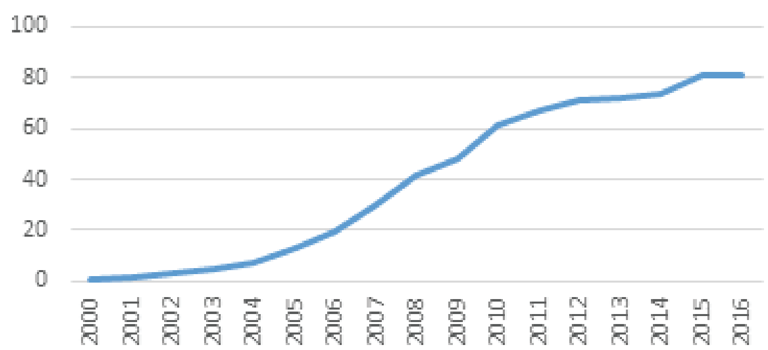
> *"We cannot do the all the work alone. There are not enough of us."*
>
> – **Joe Kheti, Kenyan Surveyor**

According to some studies, an estimated 70 percent of the property in emerging economies is undocumented and a majority of smallholder farmers around the world farm without the protection of having legal rights to their land documented by government records.[2] According to the World Bank, 62 percent of people in Sub Saharan Africa live in rural areas. In Kenya, the number is 74 percent.[3] Undocumented rural land in Africa is estimated to approximately 90 percent; in Kenya, the number is 60 percent. [4]

In February 2017, the Land Surveyors Board of Kenya states there were 108 licensed surveyors in the country with the population of about 48.46 million (or 1 licensed surveyor per approximately 450,000 people) and an area of 580,367 km^2.[5] One complaint that is often heard among surveyors is that are not enough of them to adequately document all the land in Kenya.

At the same time, Kenya is a major technology hub of Africa. The "availability of mobile technology, access to Internet, and provision of government services (referred as e- government) and open data initiative all contribute to a growing information ecosystem in the country".[6] The International Telecommunication Union states that in 2016 mobile-cellular telephone subscriptions in Kenya were 81.28 per 100 people and percentage of individuals using the Internet was as high as 26 percent. The number is likely higher in 2017.

Mobile - cellular telephone subscriptions per 100 inhabitants



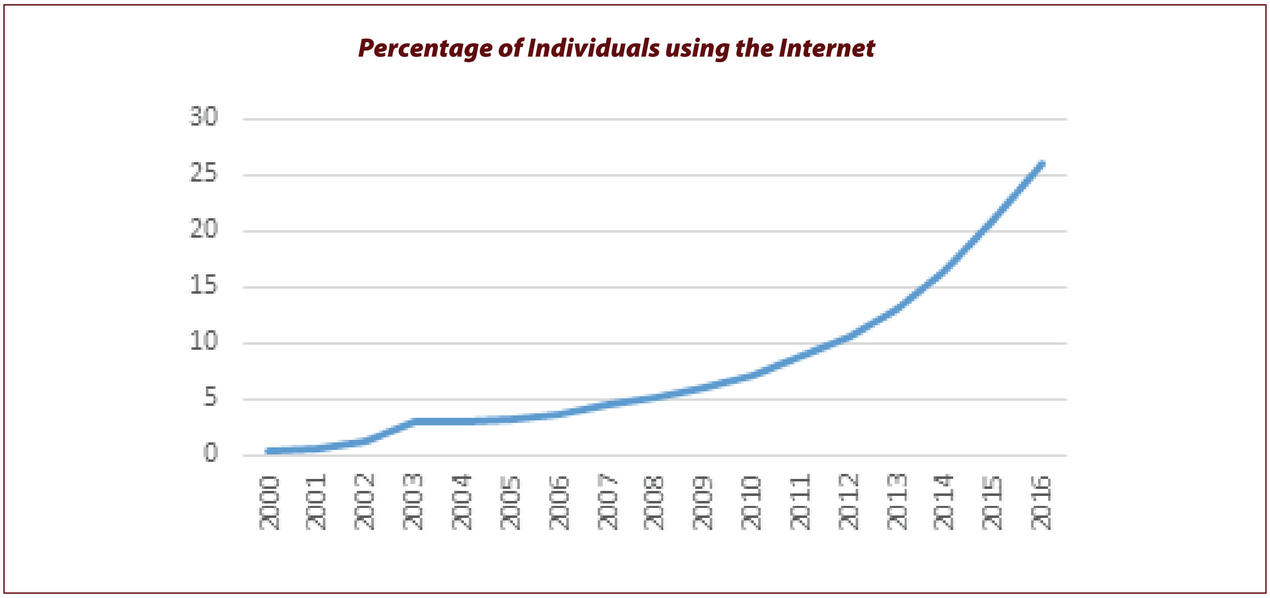
[2] *See: https://nextbillion.net/four-bottom-up-solutions-to-strengthen-land-rights-emerging-markets/*

[3] *See: https://tradingeconomics.com/kenya/rural-population-percent-of-total-population-wb-data.html*

[4] *See: http://www.ardhi.go.ke/?p=718*

[5] *See: http://www.lsb.or.ke/membership/licensed-surveyors/*

[6] *Kovačič, Primož and Jamie Lundine. 2014. "Mapping Kibera. Empowering Slum Residents by ICT." In Bits and Atoms: Information and Communication Technology in Areas of Limited Statehood, edited by Steven Livingston and Gregor Walter-Drop, 115-129. New York: Oxford University Press*



Information and communication technology tools are widely used in development in Kenya, with more focus on the poor and the marginalized as the producers and innovators with ICTs.

Initiatives and innovations that target "land matter", as it is often called in Kenya, have been somewhat scarcer than initiatives and innovations in other sectors. However, there are some activities currently planned or ongoing in the country that touch on land management. For example, the Kenyan government plans to digitize all of its 57 land registries, introduce digital mapping, and complete the national spatial infrastructure by 2022..[7]. The country also aims to use space technology to help ascertain property boundary rights registration and issuance of land title deeds to millions of applicants.[8]

While these are mainly top-down initiatives, our research looks at off-the-shelf, easy to use, hand-held mobile and GPS units and their potential role in community's participation in land demarcation and land registration. We believe that the learning curve for these tools is less steep than perhaps for other technologies, since these tools are ubiquitous and often used in other aspects of life in Kenya, such as communication, entertainment, access to information, Internet, and mobile banking.

[7] *See: https://www.delivery.go.ke/flagship/registrydigitization*
[8] *See: https://www.nation.co.ke/news/Ministry-to-use-space-technology-in-land-mapping/1056-4115066-1olvpy/index.html*

Selection of Tools

To follow the principle of using affordable modern technology for demarcation of boundaries, we selected the following tools for testing:

GPS

Device	Cost	Mode of data capture	Use of device
Garmin e-Trex 20	USD 200	GNSS signals	Recreational, General surveys
Trimble TDC100[9] (Smartphone with improved GNSS)[10]	USD 1200	GNSS signals	Professional data collection
Bad Elf GNSS Surveyor (Bluetooth GNSS)	USD 600	GNSS signals	Geospatial data collection

Mobile

Device	Onboard GNSS chipset	Year of Manufacture	Operating System	Cost	Compatible with Bluetooth Device
Samsung Galaxy S7	Exynos 8890	2016	Android	USD 670	Yes
Samsung Tablet A 8 inch[11]	Qualcomm Snapdragon 410 processor	2015	Android	USD 280	Yes
Infinix Zero 4 Plus	Mediatek Helio ×20	2016	Android	USD 320	Yes
iPhone 6s	A9	2015	iOS 9	USD 650	Yes

9 Due to issues with the shipment and customs this device did not arrive on time for testing.
10 Not able to test the tool, due to a delay in shipment.
11 Not included in the research in the end

These GPS and mobile tools were selected because they are among the most commonly used brands in Kenya, had the newest chipset technology at the time, their cost is permissible for use by the communities or a local NGOs, and have the most commonly used operating systems in Kenya.

These tools were compared to a professional-grade GPS unit:

Device	Cost	Mode of data capture	Use of device
Leica GPS1200 + RTK	USD 30,000	GNSS signals and RTK	Cadastral surveys, Engineering works

The Technical Thresholds Required for Demarcation of Individual and Community Land in Kenya

Following the fit-for-purpose principle, the accuracy of data capture of boundary points can be considered as a variable based on building density, topography and other requirements. In our research, we were interested to see whether affordable tools can reach the standards required by the Kenyan law for the demarcation of individual and community boundaries.

There are several ways in which boundary of a parcel can be represented and demarcated. The boundary can either be a physical, man-made or natural feature, and the accuracy of it varies whether the boundary is considered as fixed or general.

Fixed boundaries are high precision boundaries and used mostly in urban areas. Permanent marks (beacons) are put on the ground to demarcate land whereby their details, including coordinates, are kept at the respective survey offices and can be replaced in case they are lost or tampered with on the ground. The accuracy required for the demarcation of new boundary points for fixed boundaries is **± 4 centimeters.**

General boundaries are less precise boundaries defined by natural features such as rivers, streams, trees, rocks, ridges, etc. The accuracy of these boundaries are as low as **± 3 meters** depending on the corridor/area. These boundaries are mainly found on agricultural lands and in rural areas.

The process of land demarcation touches on either creating new grants or on subdivision of existing grants for both fixed and general boundaries. A creation of new grants represents a transfer of rights between government lands to private lands, while the subdivision of existing grants points to dividing the land into smaller pieces.

Process of land demarcation for fixed boundaries:

- **New grants**
  - National Land Commission (NLC) gives allotment letters to individuals.
  - Individual is required to pay a certain amount for allotment to become valid.
  - Once the amount is paid, beaconing is done by the surveyor as per required accuracies (± 4 centimeters).
  - Computation files and survey plans are prepared and signed by a licensed surveyor and submitted to the Director of Surveys for checking and authentication.
  - Deed plans are prepared, the new Land Record (LR) numbers offered and submitted to the Survey of Kenya for checking and authentication.

- **Subdivision**
  - A subdivision scheme plan is prepared by the surveyor.
  - The plan is then signed by a registered physical planner and a copy of the existing title deed is attached to it.
  - Once the subdivision scheme plan has been approved and a copy of the title deed attached, National Environment Management Authority (NEMA) publishes a public notice to which it attaches a copy of the Part Development Plan (PDP) and sends it to ministry of lands and physical planning.
  - Once the subdivision scheme plan is approved, the land may be subdivided. This is granted by the respective county government.

- The surveyor delineates the land and puts in the beacons at boundary points (accuracy ± 4 centimeters).
- A computation file and a survey plan are prepared and signed by a licensed surveyor.
- They are then submitted to the Director of Surveys for checking, corrections, and authentication.
- Deed plans are prepared and the new LR numbers are offered and submitted to the Survey of Kenya for checking and authentication.
- A copy of the old title deed is submitted to the lands department where it is revoked and new titles are released

Process of land demarcation for general boundaries:

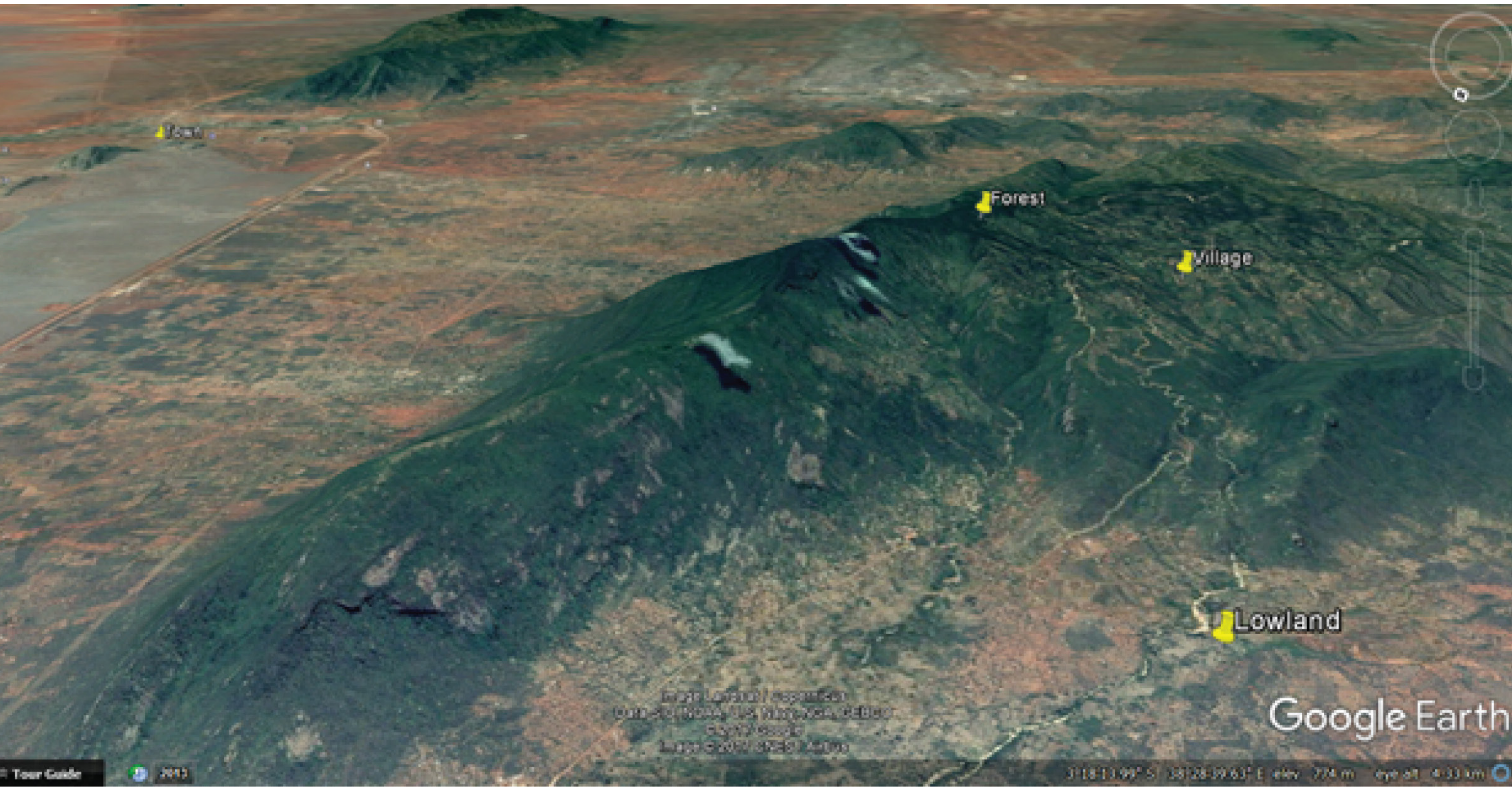
- **New grants**
  - The government decides to adjudicate a certain area.
  - Director of Surveys sends land adjudicators to the area for confirmation.
  - Adjudicators collect names and other relevant information, such as approximate area of each parcel, of the owners of these lands, etc.
  - Adjudicators delineate the land usually using a measuring tape and a pen and paper (accuracy ± 3 meters).
  - Title deeds are prepared and distributed to new owners.
- **Subdivision**
  - Search is facilitated at the local county survey office for the Land Reference number (LR) for the plot in question.
  - Information on the owner of the land and the approximate area of the land in question are collected.
  - A subdivision scheme plan is then prepared.
  - The title deed (if applicable), LR number, information on the owner and on land, and the subdivision scheme plan are gathered and attached to the application for the consent to subdivide.
  - The mutation form (indicating the information on land, the title deed (if applicable), and IDs of the owners) is prepared, filled, and signed.
  - Documents are submitted to the district board for checking and authentication.
  - The mutation form is forwarded to the land registrar for registration and titling where the old title deed is revoked and new title deeds with new LR numbers are offered.
  - Once the consent to subdivide is granted, the surveyor goes to the ground to delineate the land (accuracy ± 3 meters), often using measuring tape and pen and paper.

Can the Affordable Tools Reach the Threshold Required in Terms of Accuracy and Attribution?

Study Locations

For the purpose of this study, simple accuracy and precision tests were done in Taita Hills, Kenyan Coastal Region. The hills provide a number of locations within a compact study area that give a variety of environmental conditions, namely:

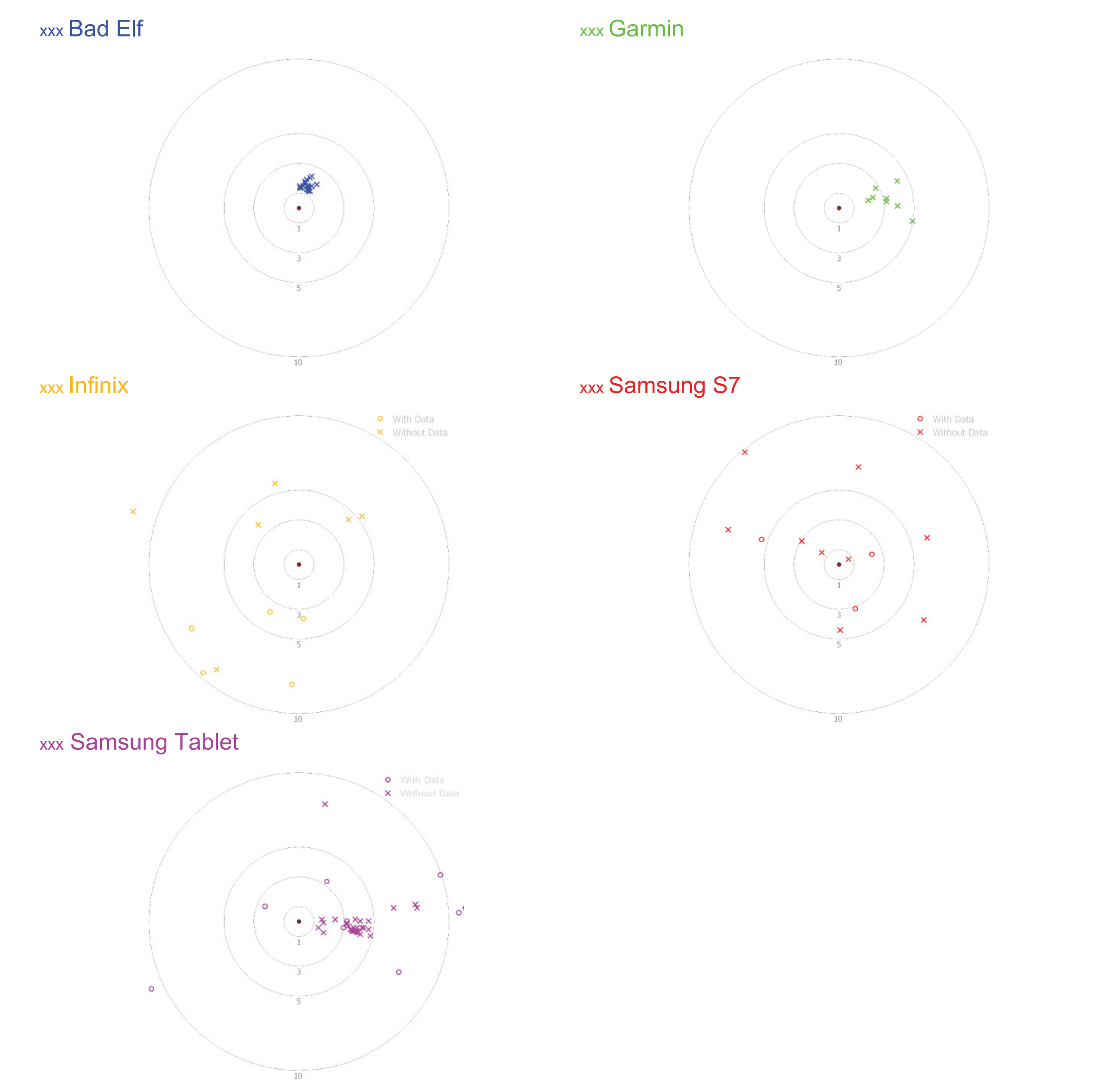
1. Forested land in the hills (high altitude).
2. Village communities consisting of subsistence farming in the hills (mid altitude).
3. Savannah, relatively flat, farmland with open canopy (lower altitude).
4. Urban environment represented by the town of Voi (lower altitude).



Ideal Scenario

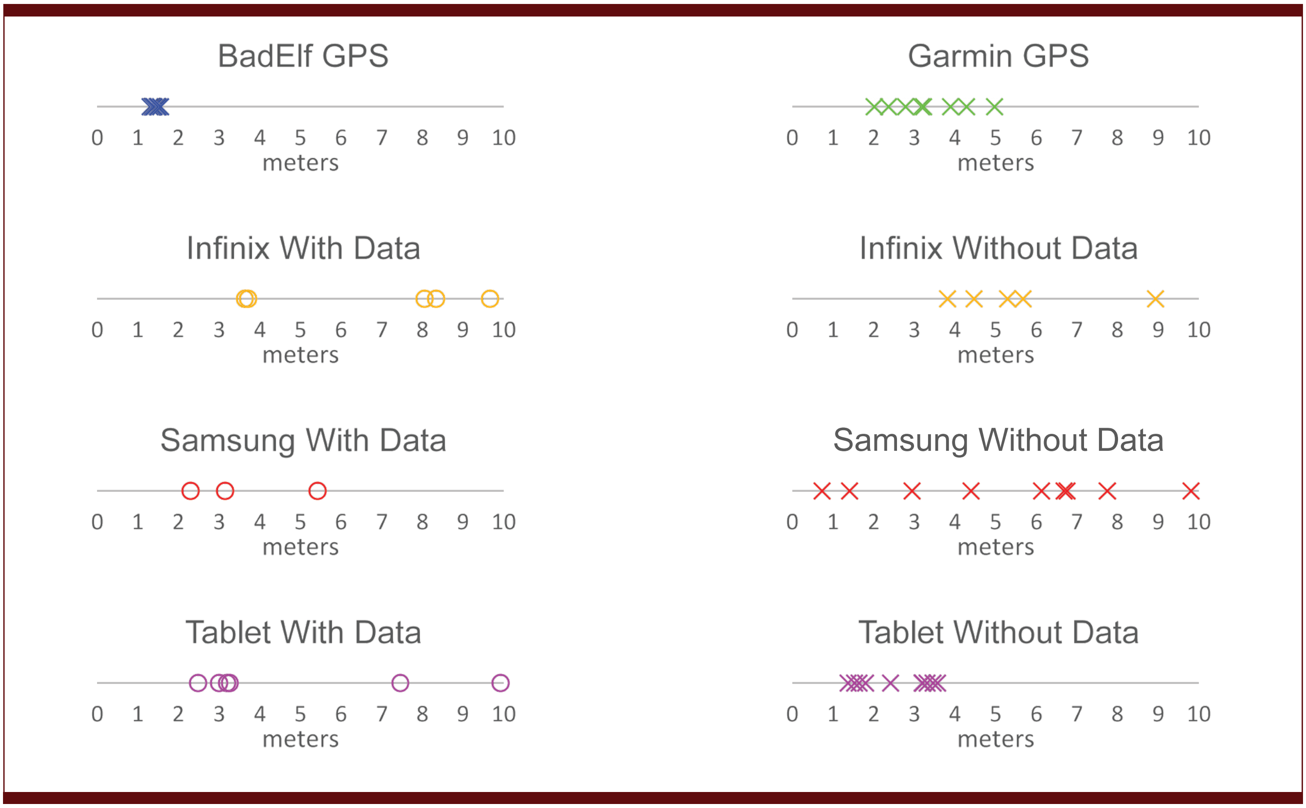
Even under what can be considered ideal conditions with a clear field of view and good mobile network connectivity, there's a certain level of accuracy and precision of location measurements that each tool can achieve.

Accuracy refers to the closeness of a measured value to a standard or known value and precision refers to the closeness of two or more measurements to each other. When we placed our GPS units and mobile phones above a known trigonometric point to demonstrate what type of accuracy and precision can be achieved in ideal circumstances, we found that accuracies and precision of tools vary.



As we can see, the points taken with GPS units (BadElf and Garmin) fall between 1 and 3 meters from the known trigonometric point while the points taken with mobile devices fall between 1 and 5 meters.

The charts below indicate the precision of measurements under these ideal conditions.



As we can see the measurements of GPS devices are relatively precise, especially the measurements of the Bad Elf GPS unit. The precision is indicated with the closeness of points on the horizontal line. Also, access to the network data (with or without data) does not affect the accuracy or precision of the measurements of mobile phones

How does this relate to the real-world scenarios?

Beyond their technical specifications, the performance of each tool to collect location data is also affected by a variety of environmental factors, in particular those narrowing the field of view to obtain mobile connectivity or be in line of sight of satellites.

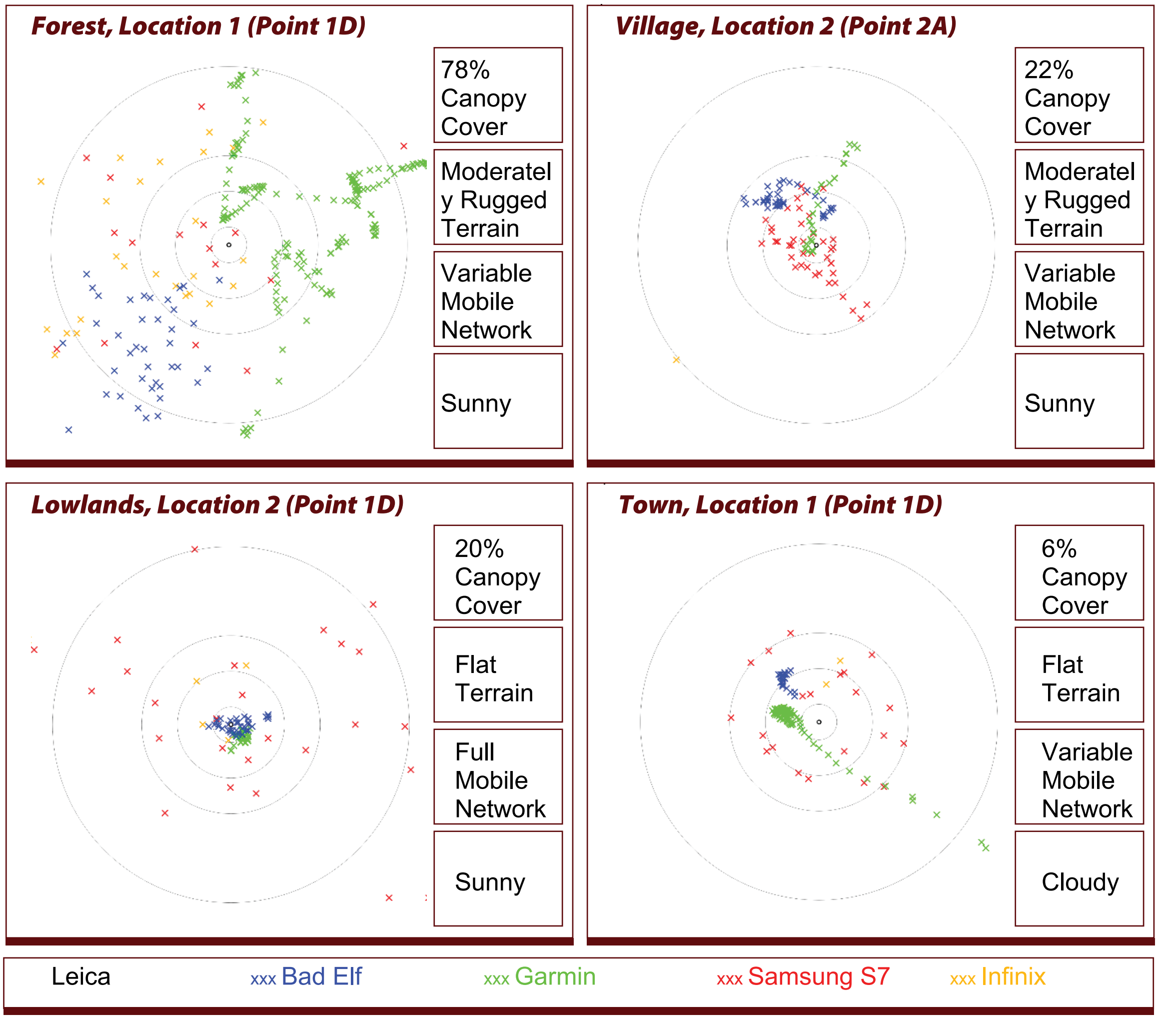
Our particular interest was how canopy cover, terrain, mobile connectivity (for mobile devices), and survey conditions,[8] affect accuracy and precision measurements of boundary points of parcels.

The purpose of this exercise was not to conduct rigorous scientific measurements of each tool but rather to test how the environment affects the measurements of locations with specific focus on the demarcation of land.

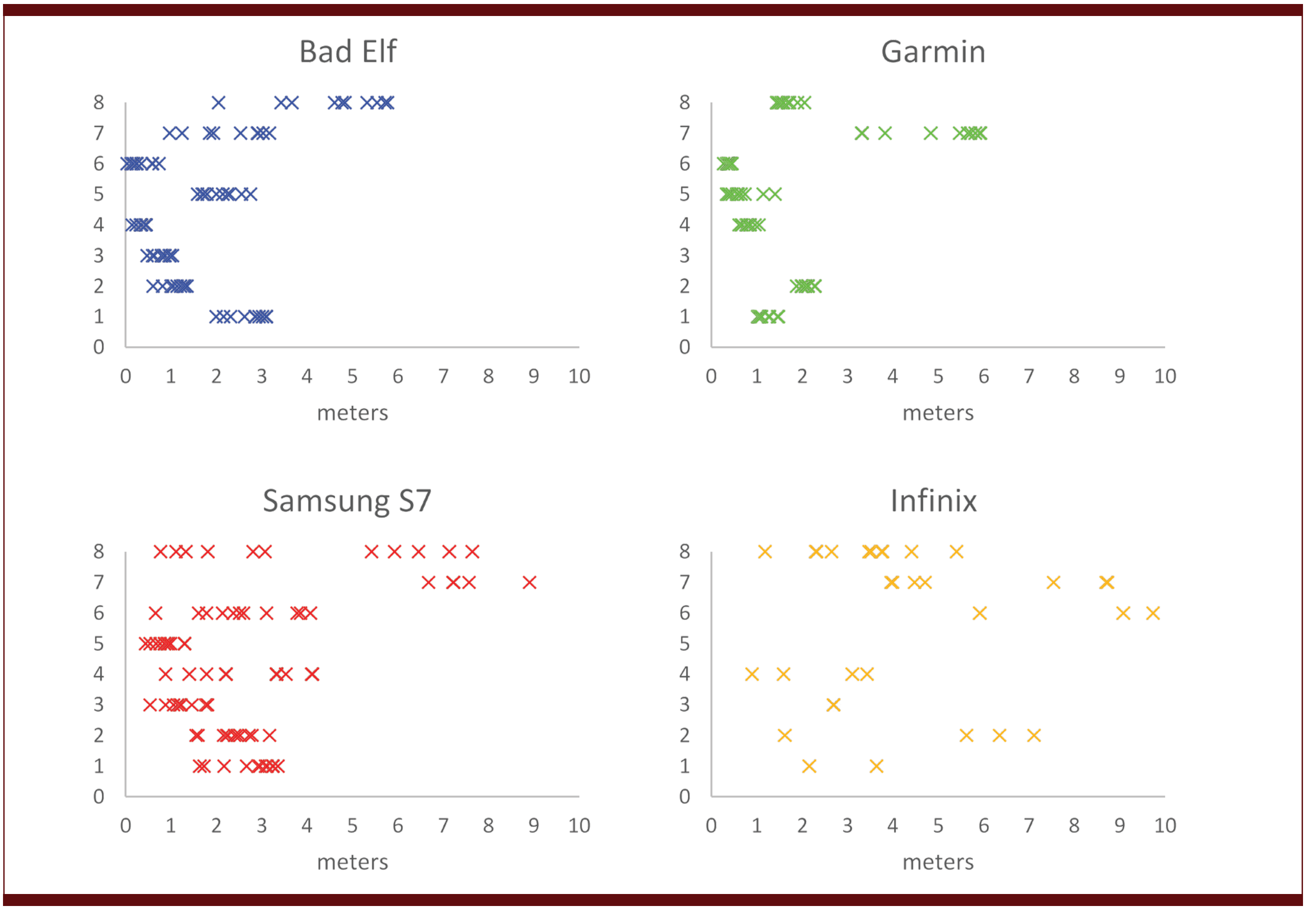
Eight sites with varying environmental conditions were selected for testing. At each site, a reference point was measured with Leica Real Time Kinematic GPS which is capable of very precise measurements (up to a millimetre). Each device was then placed on top of the reference point where location data was continuously collected continuously collected for about 10 minutes. We find that **environmental factors significantly affect the nature of measurements.** Lower accuracy and precision were observed in the forest with high canopy cover and low field of view for all devices. The measurements improved significantly as the environmental factors (canopy and terrain) improved, in the village and lowlands. Relatively high canopy cover and low field of view had the greatest effect on the measurements.

Variable network connectivity conditions were observed in the village and in the forest; however, as the first test in Nairobi showed, **network connectivity did not have a significant effect on improving accuracy and precision of measurements.**

A much higher relative accuracy and precision were obtained by the two GPS devices (Bad Elf and Garmin) compared to the mobile devices. These two devices have superior GNSS chipsets to those of the mobile phones.



If we place top ten measurements for each device on the horizontal line that indicates the distance measured from the reference point, we see that the measurements have higher accuracy (proximity to reference point) and precision (proximity to each other) under the more favorable environmental conditions (canopy cover and terrain).



Vertical line represents a canopy cover: 8 = 78%; 7 = 48%; 6 = 32%; 5 = 22%; 4 = 20%; 3 = 13%; 2 = 7%; 1 = 6%

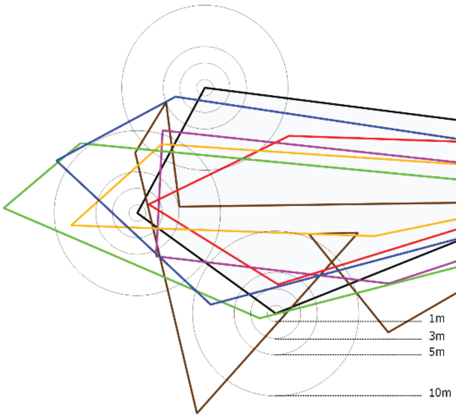
How do these findings affect individual parcel measurements?

If the previous tests give practitioners a rough idea of what to expect in terms of each device's relative accuracy and precision as they relate to various fieldwork conditions, the next test indicates how this affects the capture of boundary points and the demarcation of individual parcels.

For this experiment, ten parcels with varying environmental conditions were measured with a Survey grade GPS unit (Leica1200 with RTK) for reference. At each reference boundary point, the location was obtained using one of the devices, and specific records of the terrain, canopy cover, network availability, time of data capture, and ability to collect a point on each application were recorded.

Ten parcels were measured using Garmin e-Trex and Bad Elf GPS units, Samsung S7, Infinix Zero 4 Plus, Samsung Tablet, and an iPone, and overlaid on top of parcels measured with professional grade Leica GPS.

Forest Plot 1



Scale 1:500

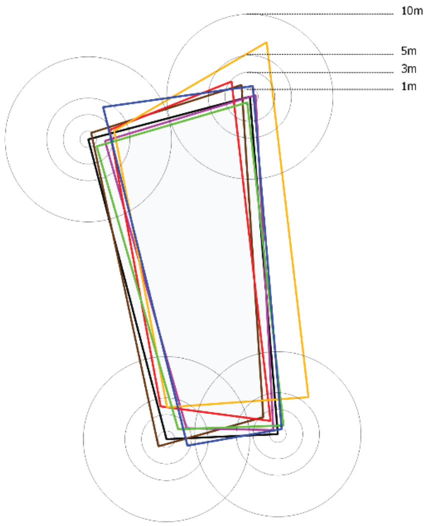
80% Canopy Cover

Moderately Rugged Terrain

Variable Mobile Network

Sunny

Village Plot 3



Scale 1:500

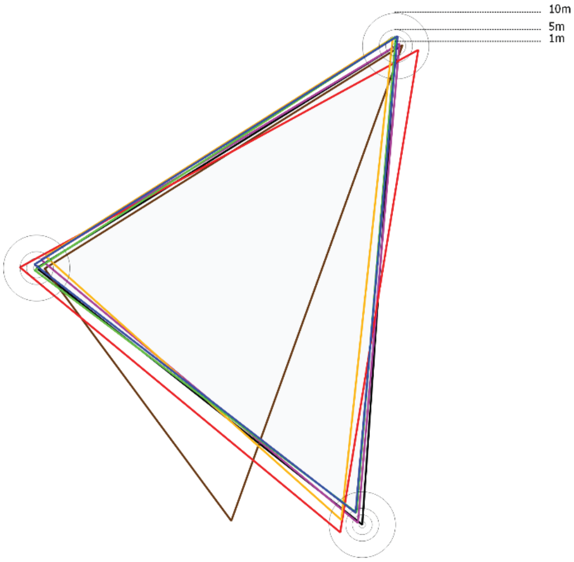
36% Canopy Cover

Very Rugged Terrain

Variable Mobile Network

Sunny

Lowlands Plot 2



Scale 1:1250

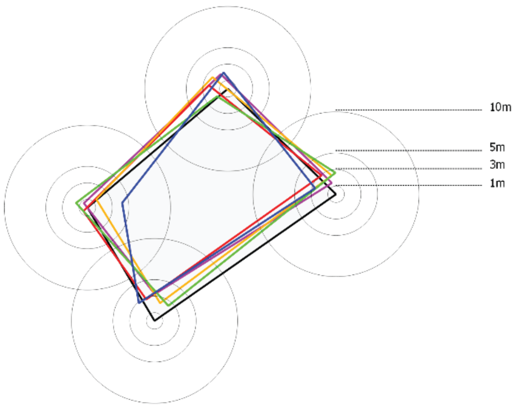
26% Canopy Cover

Flat Terrain

Full Mobile Network

Sunny

Town Plot



Scale 1:500

19% Canopy Cover

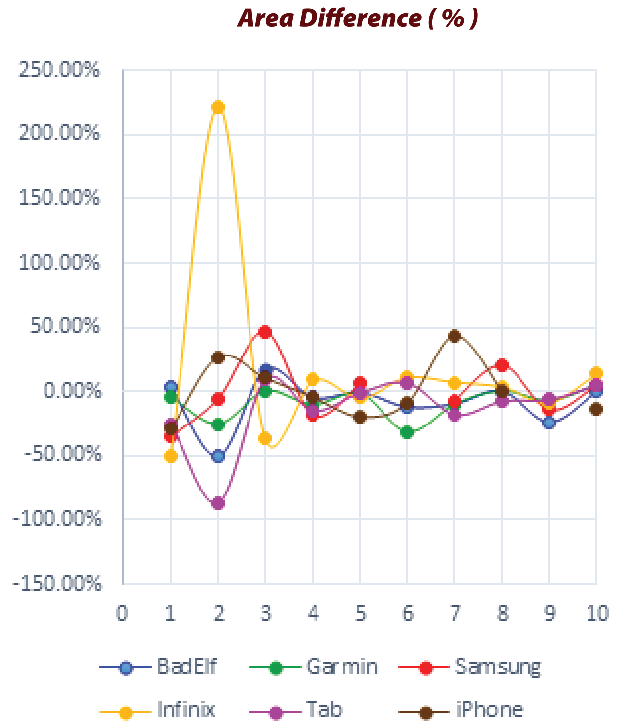
Flat Terrain

Variable Mobile Network

Cloudy

| Leica | Bad Elf | Garmin | Samsung S7 | Infinix | Samsung Tablet | iPhone

If we compare the areas of parcels measured with each device, we see that the difference in the areas measured changes based on environmental factors. In these measurements, we combined the canopy cover and field of view into one indicator called Canopy Cover expressed in percentage points. As demonstrated in this chart, the **results improved when field of view increased and canopy cover decreased.**



Horizontal line represents a canopy cover: 1 = 80%; 2 = 66%; 3 = 37%; 4 = 36%; 5 = 26%; 6 = 24%; 7 = 22%; 8 = 20%; 9 = 19%; 10 = 16%

According to one professional surveyor:

> *"Canopy cover and field of view are two things that influence the GPS measurements the most."*

Did these selected affordable tools reach the threshold in terms of accuracy?

The answer is yes and no.

These tools cannot reach the accuracy threshold required for demarcating fixed boundaries as these boundaries require three to four centimeter accuracy under the Kenyan law. Apart from the professional grade GPS unit, none of the tools reached this level of accuracy. However, apart from the heavily forested areas, **most devices were able to collect location data within three to five meters, as required for general boundaries.**

Can the Community Replicate the Work of a Professional Surveyor Using These Affordable Technologies?

Our particular interest was to gauge the limits and benefits of using affordable and widely available tools for demarcating land boundaries in Taita Hills as compared to heavy-duty professional surveying equipment.

To see whether community can itself replicate the work of a professional surveyor, two simultaneous boundary/land captures of the same series of parcels were done. The first involved a surveyor conducting a cadastral survey of the parcels using survey grade equipment, the second, community mappers using off-the-shelf GPS or a mobile devices.

Apart from collecting locations of boundary points, attribute information on parcels was also captured.

Surveyor's process of land demarcation

In our research, we considered that the areas of focus have never been mapped before. Since these are rural areas, with land use predominately consisting of subsistence farming, we chose the process of creating new grants. In this case, when the government decides to adjudicate a certain area the following steps are taken:

- Director of Surveys sends land adjudicators to the area for confirmation.
- Adjudicators collect names and other relevant information, such as approximate area of each parcel (just by collecting information from the owner and by his/her own estimates) and information on the owners of these lands.
- Adjudicators delineate the land usually using a measuring tape and a pen and paper with accuracies of up to ***± 3 meters or less.***
- Title deeds are then prepared and distributed to new owners.

Once the surveyor reached the parcel in question, he gathered the following information from the owner and wrote it on a piece of paper:

- Name of the owner
- Personal identification number of the owner
- Any other relevant information concerning the plot

In rural areas, general boundaries are considered sufficient. However, in our case, the surveyor conducted a proper cadastral survey of fixed boundaries of the parcels using a professional-grade GPS unit. By approximating the highest standards for land demarcation, we tried to set the bar high. Surveyor's system consisted of a base station and a rover. He used a professional-grade Leica GPS1200 and Real Time Kinematic (RTK) technique for data capture. The accuracy of points was ***two to four centimetres.***

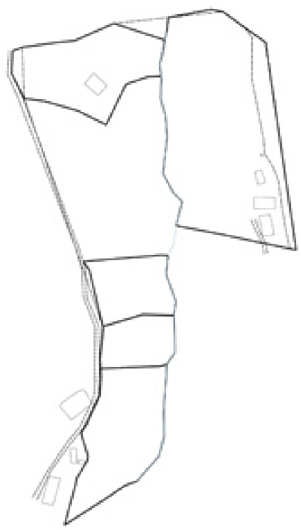
The Surveyor then accompanied the owner to each boundary location, collecting points along the way.

Following these steps, the surveyor ensured that under the Kenyan law the owner's parcel was correctly captured and necessary paperwork done.

The screenshot below displays the raw data collected by the surveyor:

No.	Northing	Easting	Height	Code	Code Desc
1	9632185.4	436833.4594	1221.2394	RDE	ROAD EDGE
2	9632185.771	436830.1713	1221.1049	RDE	ROAD EDGE
3	9632179.771	436829.4254	1222.3139	RDE	ROAD EDGE
4	9632179.132	436833.0812	1222.2725	RDE	ROAD EDGE
5	9632196.456	436824.0259	1219.0029	PB	PARCEL BOUNDARY
6	9632213.49	436824.6014	1213.2397	PB	PARCEL BOUNDARY
7	9632216.224	436831.8964	1211.9244	FL	FENCELINE
8	9632219.876	436857.8976	1211.2392	FL	FENCELINE
9	9632221.167	436871.2846	1211.9118	FL	FENCELINE
10	9632221.16	436871.3015	1211.8988	FL	FENCELINE
11	9632220.798	436882.991	1212.9645	TR	TREE
12	9632234.201	436900.9572	1212.4342	FL	FENCELINE
13	9632220.669	436939.1373	1197.1268	TR	TREE
14	9632194.195	436926.8325	1201.7501	TR	TREE
15	9632188.646	436910.172	1211.4233	TR	TREE
16	9632188.013	436908.2202	1212.7296	TR	TREE
17	9632158.238	436895.2686	1223.5435	TR	TREE
18	9632168.999	436873.1733	1222.4539	TR	TREE
19	9632175.906	436848.6037	1222.6419	TR	TREE
20	9632177.929	436833.4677	1222.7425	FL	FENCELINE
21	9632188.966	436878.9743	1219.9851	BC	BUILDING CORNER
22	9632180.154	436889.2087	1219.6935	BC	BUILDING CORNER
23	9632187.732	436895.939	1218.2002	BC	BUILDING CORNER
24	9632196.906	436885.6856	1218.4052	BC	BUILDING CORNER

The map of plots documented by the surveyor:

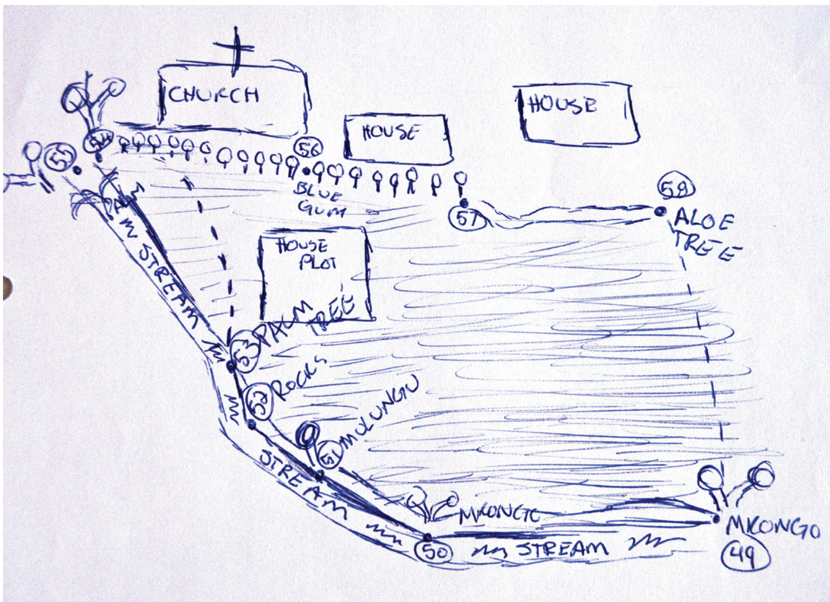


Community's process of land demarcation

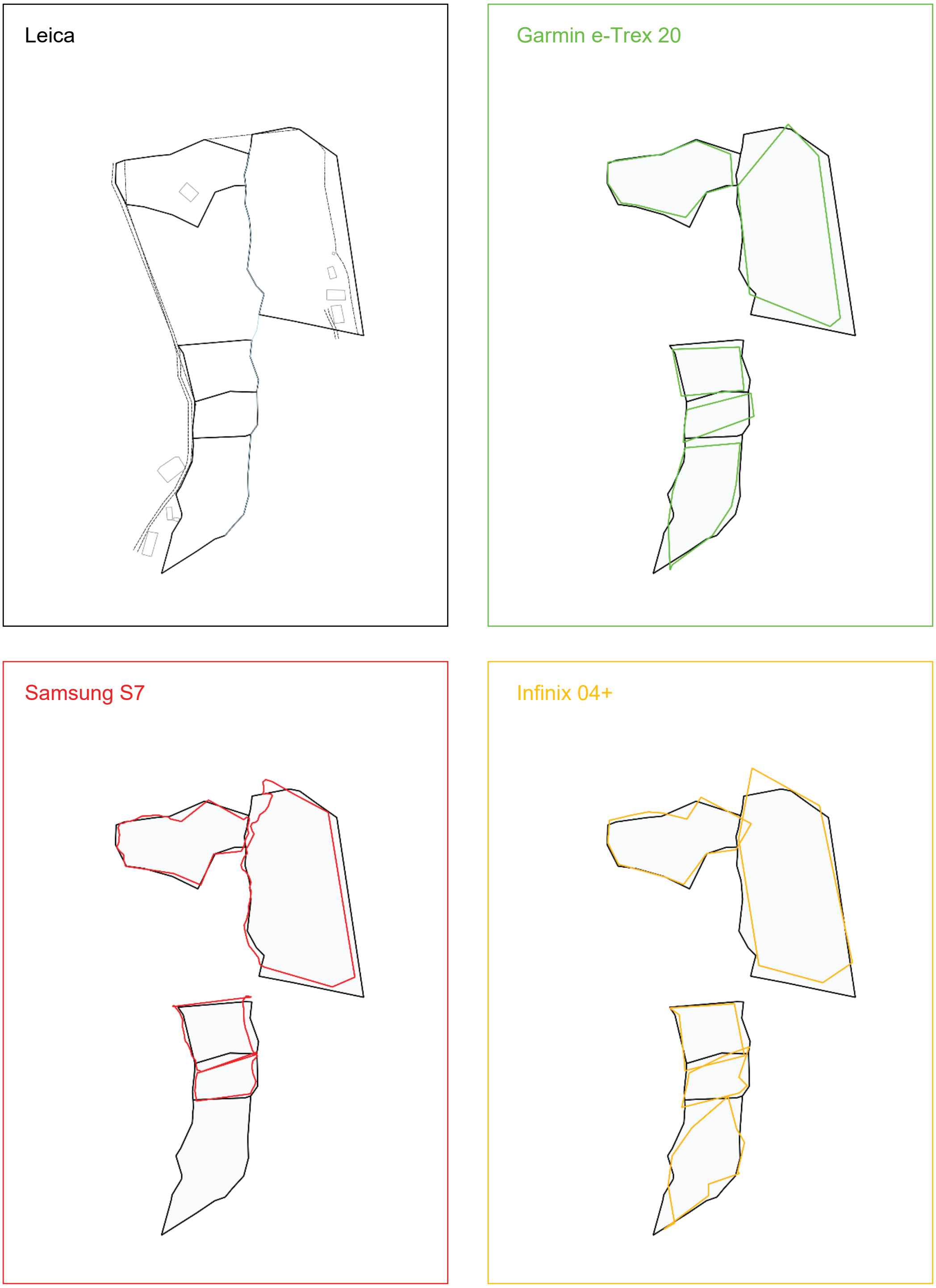
The community mappers initiated the work by conducting interviews with owners. They collected the following information:

- Information on the owner, including name, ID, date of birth, mobile number, email, sex.
- Physical address of the plot, such as county, sub-county, sub-location, postal address.
- Information on land, including plot name, reported acreage, land use, resources, and assets.
- Information on property right, such as availability of title deed, type of title deed (owner, leaseholder, tenant), sole ownership or shared, other persons with rights to land, date of purchase, any disputes on land, any other difficulties.
- Information on easement and right of way.
- Locations of boundary points using affordable technologies (hand-held GPS units, mobile phones and a tablet).

After the interview was complete, the community mapper accompanied the owner on foot to all the boundary points of the parcel and drew a sketch map of it. As noted above, a sketch of the parcel, coupled with measurements collected with a measuring tape, is sufficient even by the government standards. In rural areas, a sketch map with a pen and paper is usually the mode with which the surveyors collect spatial data about the parcels. These drawn maps together with other information on the land are then stored in paper format in local offices.



After the sketch of the parcel was complete, the community mapper used either an off-the-shelf GPS or a mobile phone/tablet to collect the boundary points of the parcels.


Leica
Garmin e-Trex 20
Samsung S7
Infinix 04+

For the purpose of this exercise, the accuracy obtained with the Leica instrument was between two and three centimetres. This type of accuracy is sufficient for capture of fixed boundary points. It is noted that this type of accuracy is not required under Kenyan law in these particular circumstances (to demarcate the boundaries of subsistence farms in remote rural areas). Boundary points in such an environment are usually captured as general boundaries, with accuracies anywhere between three and five meters or less.

The comparison of affordable mobile and GPS devices to the Leica instrument shows that while the affordable tools are not suitable for the capture of fixed boundaries, **they are more than suitable for the capture of general boundaries in rural areas.**

Comparison of attribute data obtained

The surveyor obtained the following attribute information:

- The name of the owner or owners.
- Personal ID of owner or owners.
- Supposed acreage of the plot.
- During fieldwork, the surveyor captured the boundary points with accuracy between two to three centimetres.

By contrast, the community mapper used a pre-designed questionnaire and gathered the following information:

- Information on the owner, such as name, ID, date of birth, mobile number, email, sex.
- Physical address of the plot, such as county, sub-county, sub-location, postal address.
- Information on land, such as plot name, reported acreage, land use, resources, and assets.
- Information on property right, such as availability of title deed, type of title deed (owner, leaseholder, tenant), sole ownership or shared, other persons with rights to land, date of purchase, any disputes on land, any other difficulties.
- Information on easement and right of way.
- During fieldwork, the community mapper captured the boundary points with accuracy between one to five meters.
- Acreage of the parcel.
- Pictures of land and of boundary points.
- Pictures of owners, their ID's.

As we can see, **community mappers using affordable technologies can easily capture attribute data required by the professional surveyor during the demarcation of land.**

Advantages and disadvantages of using each device for land mapping

Advantage of using a professional grade surveying equipment:

- Accuracy. The tool has the ability to collect location to a millimetre; an accuracy which suffices for all cadastral surveys and most engineering surveys.
- Ability to pre-program on-the-go data collection. This feature enables data capture of boundary points and other necessary amenities in one go.

Disadvantages of using a professional grade surveying equipment:

- The equipment itself is very bulky and often requires at least two operators, especially in the difficult to access terrain.
- Extremely high price of the device and out of reach for communities.
- When dealing with parcels in rural areas the accuracy that the tool offers (millimetre or centimetre) is not necessary.
- Not a scalable solution to document tens or hundreds of thousands of undocumented parcels.
- Single use only. The device can only be used for capture of boundary points.

Advantage of using the mobile phone and mobile application:

- The mobile phone is light, easy-to-use, and affordable.
- In terms of data collected, the mobile application can be programmed to capture both boundary information (locations of boundary points) and detailed attribute information on the parcel.
- They store information in the digital form, directly into the device or with internet connection anywhere in the cloud. Data can be transferred directly from the field into the cloud for safe storage; this is if internet is available, if not, data can be transferred once internet is available.
- Phones enable image capture which can be used for documenting owners, boundary points, signed documents, and other amenities.
- Touching on the point above, data can easily be shared among intended users; although, privacy concerns would have to be considered.
- During the boundary or polygon capture, the community mapper has an option of using automatic tracing by walking around the plot. This feature can be useful when capturing curvilinear boundaries such as rivers and roads.
- Mobile technology represents a significant upgrade to the pen and paper method. One surveyor explained the benefits of mobile technology for land mapping in the following way:

> ***"Oftentimes, we have to take all of the printed, official documents with us to the field. They can get lost, rained on, or otherwise destroyed. Having everything in a portable device could make our work much easier. We could take pictures of owners, boundary points, etc. and then link those pictures to the parcel."***

Disadvantage of using the mobile phone and mobile application:

- Accuracy of spatial data. Accuracy is relatively low compared to the professional tools and even off-the-shelf GPS units.
- Wear-and-tear. Mobile devices are not built for field work and can be damaged easily.
- Phones do not allow for capture of points that are not necessarily related, meaning, they can only capture one polygon at a time to which all of the attribute data is associated. This means that once the mapper starts collecting boundary points, he/she has to finish collecting boundary points and can't switch in between collecting other relevant landmarks. The application does not allow for a point based data collection system that the surveyor uses. This is one shortcoming of the application in a sense that it doesn't allow for agility during the field work. The mapper cannot record separate features on-the-go but has to always finish one task first (like collecting all the boundary points) before moving to another (collecting infrastructure or natural

features of the land). The attribute data is always attached to the most current task.

- Inability to collect an offset point. Oftentimes, the data collector finds him/herself in a situation where the boundary point cannot be reached for various reasons, such as if the point is in a gorge, at the escarpment, in a steep rock face, etc. In these situations, an offset point is used to locate the boundary. This can be used either by moving the spatial location manually in the software to the necessary location, or to assign a special meaning to the point (For example: "move that point 10 m north").

Comparison between the community mapper's and the professional surveyor's approach

One of the main goals of this research was to see whether community mappers can replicate the work of a professional surveyor by using off-the-shelf tools.

Some differences between approaches are:

- The surveyor's approach is the only officially recognized approach by the Kenyan Government.
- The surveyor, apart from collecting boundary points, also collects terrain features and topography features which surround each boundary point. The community mapper using the mobile phone can take pictures of boundary points and their surroundings.
- The community mapper comes from the community. The trust among fellow community members and the community mapper is much higher than between the community and an outside surveyor.
- The community mapper's process is flexible. There's no limit to how much information the mapper (community) can collect. The surveyor only focuses on the basic necessary information (information on owner, boundary points, land use, disputes if there are any).
- The process that the community mapper uses is transparent. Because the tools are fairly simple, they are much easier to comprehend. The surveyor on the other hand uses tools and methods that require a steep learning curve.
- Last but not least, the community mapper's process is replicable on a large scale and is more sustainable for communities. There are not enough surveyors in Kenya (and most other developing countries) to capture all undocumented land. On the other hand, the low cost and ubiquitous tools, replicable straight-forward process, local knowledge, but mainly, the sheer number of possible community mappers can fill in the gaps left by governments and professionals. However, for community land mapping to become an acceptable standard, additional data cleaning and validation, privacy and security processes should be considered.

Comparison of costs

Item	Surveyor	Community Mapper
Day rate	USD 50 (per hour)	USD 10 to 30 per day (between USD 1.25 and 3.75 per hour)
Survey	USD 100[12] per parcel (plus 3% of the market value of the land)	N/A
Equipment:		
Leica GPS 1200 + RTK	USD 30,000	
Average mobile phone		USD 150
Garmin e_Trex 20		USD 200
BadElf GPS		USD 600
Beaconing	USD 10 (per beacon)	N/A
Travelling and subsistence	USD 30	USD 10
Other Costs:		
Boundary dispute resolutions	USD 20[13]	N/A
Required documents (*consent form, search form, mutation form, deed plan, titles*)	USD 40	N/A
Land Board Fees	USD 10	N/A

The surveyor costs above are standard as per the Survey Regulations, 1994. The community mapper costs are based on market prices and the field work operations we undertook.

Let us consider a hypothetical example of a parcel with 10 boundary points. The professional surveyor can take up to minimum two hours to complete the work (this includes the process of talking with the owner to setting up the equipment and taking the points). For this work, the professional surveyor would charge at minimum USD 380[14] for the demarcation of the parcel + plus 3% of the market value of the land. This only considers the cost of man-hours to complete the work and when there are no disputes on the land.

This cost is likely prohibitive for most rural communities in Kenya where according to some statistics, the prevalence of absolute poverty in rural Kenya was still almost 50 percent.[15]

To demarcate the same piece of land to create a digital signature of it, the cost for a community mapper for the same parcel can be as low as USD 20 per parcel.[16]

12 *For each plot of land Ksh 10,000H (where "H" is the square root of the area in hectares, of the plot).*
13 *Sh. 2,000H (where "H" is the square root of the area of the complaints parcel in hectares).*
14 *(USD 50 per hour x 2 hours + USD 100 per parcel + USD 10 x 10 beacons + 30 travel and substance + USD 40 for documents + USD 10 for Land Board Fees)*
15 *See: https://www.standardmedia.co.ke/article/2000110595/report-lists-counties-with-highest-levels-of-poverty*
16 *(USD 3.75 per hour x 2 hours + USD 10 travel)*

Lessons learnt and recommendations

In our research we aimed to test whether:

1. Cheap and widely available tools that can be used for land demarcation exist.
2. These tools can reach the demarcation threshold required be the Kenyan government in terms of accuracy and attribution.
3. Communities, using these tools, can replicate the work of a professional surveyor.

We find that **cheap and widely available tools that can be used for land demarcation indeed exist.** Kenya is a major technology hub of Africa. Mobile-cellular telephone subscriptions are higher than 80 percent and percentage of individuals using the Internet was as high as 26 percent in 2016. These new technologies "help marginalized communities communicate, conduct business, receive nearly real-time feedback from crisis areas, alert populations about health risks, fight corruption, climate change, and alleviate poverty."[14] Given the central role of communication costs in collective action, the growing abundance of cheap, broadly distributed and sophisticated information and communication technologies can affect the nature of collaboration in community-based development initiatives.[15]

When we tested a series of off-the-shelf GPS and mobile tools to see whether they can achieve the accuracy and attribution standards required by law, we found that **environmental factors greatly affect the nature of measurements of different terrains.** Lower accuracy and precision were observed in the forest with high canopy cover and low field of view for all devices. The measurements improved significantly as the environmental factors (canopy and terrain) improved, in the village and lowlands. Relatively high canopy cover and low field of view had the greatest effect on the measurements.

We find that these tools cannot reach the accuracy threshold required for demarcating fixed boundaries as these boundaries require three to four centimeter accuracy under the Kenyan law. However, apart from the heavily forested areas, **most devices were able to collect location data within three to five meters, as required for general boundaries.**

Furthermore, we found that **a pairing of mobile and GPS dependencies may provide the most optimal and cost-effective measurements** in the face of environmental and terrain challenges and limited network connectivity.

Working with communities and a professional surveyor, we find that **communities can lead the process of land demarcation and can replicate the work of a professional surveyor both in terms of accuracies and attribution** required in rural areas (general boundaries). Smart phones can store the necessary attribute data from the field in a digital format, **fulfilling the requirements to document people, land and associated rights.**

We find that these tools **provide an excellent alternative to the system that is currently used in rural areas** where most parcels are registered only through pen and paper, and sometimes by measuring tape, and information is stored in paper format at the County offices. The tools are also much **cheaper and easy to use** than the professional grade surveying equipment.

[14] *Kovacic, Primoz. 2014. Digitally Enabled Collective Action in the Areas of Limited Statehood, Implications of Information and Communication Technology for Collective Action on Hazard Mitigation and Environmental Management in Mathare, Kenya. Masters Thesis*

[15] *Kovacic, Primoz. 2014. Digitally Enabled Collective Action in the Areas of Limited Statehood.*

Some of the bottlenecks that can be removed by using these affordable technologies:

1. Lack of affordable tools.
   The tools are widely available, affordable, and easy to use by communities.

2. Local communities have no access to information.
   With these tools, information can be easily collected, stored and shared.

3. Local communities are not able to value their land.
   Applications can be built to streamline the valuation of land based on the data input.

4. The registration process is unclear or unknown to the communities.
   The tools can be used for information sharing.

5. The relationships between Kenyan national, community and individuals in terms of property rights is difficult for communities to comprehend.
   This is a systemic issue that the tools cannot address on their own.

6. Antiquated procedures sustained through inertia in the titling process and an inability to explore, let alone adopt new technologies to replace old methods.
   This is still an issue in Kenya, however, the tools provide for an excellent alternative to the current system of paper based data storing, etc.

7. Technical tools used to capture vital information on mapping are often too expensive, difficult to operate, rely solely on connectivity, and require extensive training/maintenance and complex processing solutions. In some cases the skills needed to record information accurately often built up over many years of experience including formal qualifications.
   Training is relatively simple and most processes repeatable to a satisfactory standard, and the possibility of having units available at sub-county level that can be rented out to communities makes it cost effective and affordable.

As practitioners, we see the need for simplification and streamlining of some of the functionality of the various hardware and software used for documentation of community lands. **The use of affordable and widely available ICT tools can empower local people to rightfully claim land and thus eradicate future land disputes and conflicts amongst them.** There are ample opportunities for policymakers, lawmakers, technical experts, and administrators to use these insights to influence and shape their land rights agendas, as well as support efforts to better include local people and accurately map boundaries in Kenya.

Appendix

Field Guide

A criteria for selection of tools and methods for mapping community/private land

Criteria	Considerations	Options: Technical tools and logistical considerations
Enabling environment	Who are your allies? Who are your opponents? What are the risks to your staff and community members? Are community boundaries reconciled? Are the community members willing to participate in demarcation of boundaries?	Consider socio-economic, political, cultural, historic, and ethnic history of the area Gather either evidence of the following: name of the community; community facilitator assigned to the community; names of the key coordinating committee members; brief summary of the activities conducted to date and any challenges experienced with boundary harmonisation; any expected challenges (e.g. no network coverage) Remote data analysis may be a preferred option - satellite or aerial imagery analysis - if there are risks from opponents If there is broad support for the work, fieldwork with GPS and/or mobile tools may be possible
Purpose	What is the purpose of data collection?	Is the purpose of data collection awareness raising, capacity building or creating new datasets or all three? Once the purpose is established, consider what type of data that is required to achieve it: Are drawn maps of parcels sufficient for the task or do we need more precise measurements? What about if the purpose is mapping natural resources or human-wildlife interactions?

Required Accuracy	What is the accuracy required?	One of the most important question to consider is what the accuracy required is? Are fixed or general boundaries of parcels being mapped? In Kenya, fixed boundaries of parcels require less than 2 to 3 centimetres accuracy, while general boundaries between 3 to 5 to 10 meters, depending on the corridor Choose the tools based on accuracy needs
Size of the area	What is the size of the area? What tools can you use to determine the size as you are planning your work?	Speak to local people to get an idea of how long it would take to walk, drive or bicycle around the area. This will help determine if the time and resources are available are adequate Map drawing is a good exercise to determine the size of the area and features within an area Use of topographic maps or internet platforms, such as OpenStreetMap or Google Maps or Google Earth to identify the area ahead of fieldwork, and begin to estimate size
Terrain	What are the terrain types in the area of interest? Is there road access to all areas you want to map?	Terrain type affects the accuracy results through decreased or increased field of vision. It also affects time of measurements due to ease or difficulties of traversing it To prepare for whatever eventuality, use of satellite imagery, topographic maps or internet platforms, such as OpenStreetMap or Google Maps or Google Earth, can help to identify the area, terrain types and other features within the area
Canopy Cover	What is the estimated canopy cover in the area of interest?	Heavy canopy cover significantly affects data collection. For example, in forested areas, it is not appropriate to use mobile phones, GPS units or satellite imagery for boundary demarcation due to low visibility, loss of signal and subsequently low accuracy. In heavy forested areas, Total Station or even a measuring tape are viable options.

Existing data sources	Identify existing data sources (avoid duplicating efforts if data already exist)	Look at acquiring existing and available topographic maps from government agencies, open data portals (e.g. Kenya Open Data Portal, World Bank Open Data, OpenStreetMap)
Available resources (budget)	What financial resources do you have available for the project? Resources should include both labour (e.g. staff time) and direct costs (e.g. transportation, equipment, software licenses, meeting costs)	Field data collection is resource intensive Remote data analysis may not be possible if you do not have enough reference data so resource mobilization may be required
Available human resources (staff) and skill level	Who is available for the work? What is their skill level?	Consider having: a Project Manager to oversee the planning and implementation of activities; a GIS Field Manager(s) to plan and oversee field operations; Data Collectors with a field team structure to support organized data collection and coordination; Community Liaison for community relations
Mobile network coverage	Is there mobile coverage in the area?	Use hand-held GPS devices for areas with limited mobile connectivity Develop a safety and communication plan for coordinating field activities in areas of limited mobile connectivity
Season	How does the season affect possible data collection?	Choosing the right season (rainy or dry) for mapping saves time, energy and spending

Practical considerations and limitations of each tool

Several tools were tested in this research. Below, we consider practical strengths and weaknesses of each tool and practical considerations for selection of each tool. We break down the analysis of practicality of each device based on:

- What are the additional equipment needs necessary to acquire relevant and necessary data for the purpose of the task? Does the successful use of the tool and data require additional equipment?
- What is the level of skillset required to successfully operate the device and obtain the relevant data/information? We broke down the skill levels to
    - Low: familiarity with using a basic mobile phone or a hand-held GPS unit (mostly just data collection)
    - Medium: familiarity with using mobile phones and GPS units; with using computer operating systems (windows, macOS) for data management (storing, saving, sharing, transferring, etc.)
    - High: familiarity with using high-tech equipment (such as higher grade GPS units, satellite imagery, drones); with conducting spatial analysis of the data collected; with producing outputs (maps, analysis), etc.
- Is the successful operation of the tool dependent on other factors, such as access to the GPS signal, access to mobile networks, access to other devices, etc.?
- What are some of the strengths and weaknesses?

Device	Additional Equipment Needs	Skill Level Required	Dependencies	Cost Benefit
Hand-held Garmin GPS device	Computer Cable Software Batteries	Low	GPS signal Need additional tool for attribute data collection (pen and paper, mobile phone)	GPS device can be relatively affordable, easy to use, rugged, while still producing satisfying and relatively accurate results The learning curve is not significant as it only enable locations selection and havs limited options for attribute data collection. Because of the latter, it needs to be paired with an additional tool for attribute collection

Mobile Phone	Cloud for data storage Computer Charger Cable Software	Medium	GPS signal Network (although for data collection not necessary; necessary for sharing) Connection to other software where data is stored on cloud	The biggest advantage of mobile phones is that they are widely available and used in all aspects of society. Because of this, the learning curve is much smaller than for most other devices Additionally, they are relatively cheap, enable almost limitless attribute collection, and produce satisfying results in most cases, especially if paired with dependencies, such as Bluetooth GPS devices They are however prone to damage, have a short battery life compared to GPS devices, and they collect less accurate data GPS devices
Tablet	Cloud for data storage or computer with software Charger Cable Software	Medium	GPS signal Network (although for data collection not necessary; necessary for sharing) Connection to other software where data is stored on cloud	Similarly to mobile phones with addition of having a larger screen which enables better the use of satellite imagery
Bad Elf GPS	Mobile phone Batteries Charger for Mobile Phone Cable Computer	Medium	GPS signal Additional tool for data collection (mobile phone or a tablet)	This tool is a great addition to mobile phones for data collection as it diminishes the phones poor accuracy However, the tool is a bit pricey, compared to regular hand-held GPS device or a mobile phone It requires a bit more learning than GPS and mobile phone on their own as it needs to be set up

Satellite Imagery	Computer or tablet or mobile phone Charger	Medium to High	Additional tool such as computer, mobile phone or preferable a tablet GPS signal if used in the field and on-the-go	Satellite image can be used in many ways, for example, imagery can be printed and drawn on top of it; it can be used as a background for data collection on a mobile phone or tablet; or used for data evaluations

Suggested workflow diagrams and methods for the use of tools

GPS

Collect GPS location data → *Transfer data to the computer* → *Save the data* → *Import data with GIS Software* → *Export data as shape file or create a map*

Mobile Phone or Tablet

A mobile solution is a viable option for collecting data in the field. The process of data collection using mobile phones goes as follows:

Set up the questionaire on a computer → *Upload it to the phone* → *Data collection in the field* → *Save data on the device* → *Share data to the cloud* → *Import data into GIS software* → *Export data as shapefile or create a map*

Bad Elf

Connect the device to the mobile phone → *Set up the questionnaire on o computer* → *Upload it to the phone* → *Collect attribute data with mobile* → *Collect location data with Bad Elf* → *Save data on the device* → *Share data to the cloud* → *Import data into GIS software* → *Export data as shapefile or create a map*

Satellite Imagery

There are many ways to use satellite imagery for land mapping:

- Print the imagery and draw on top of it
- Use it as a background image for data collection on a mobile phone or tablet
- Use it for data evaluations

Recommended Mapping Methodology

Based on review of our methods in the main report these are the main steps to mapping individual or community land:

Pre fieldwork preparation

1. *Designing the questionnaire*

Depending on the purpose of the survey or the targeted government body, the user should create a questionnaire for data collection. If the purpose to collect data that is aligned with the government requirements, the user should use the template form from the respective authority.

2. *Criteria review*

Following the Field Guide on page 34, the user should consider the criteria and develop an appropriate methodology and tool selection for the task.

3. *Tool selection*

Following the Practical considerations and limitations of tools on page 37, the user should be able to select the most appropriate tool for data collection.

4. *Availability of data*

Proper use of topographic maps and satellite imagery can provide better estimates for planning of community mapping work. Adequate time should be allocated for a reconnaissance mission and collection of relevant secondary data (topographic sheets and satellite imagery). Additionally, sketch maps are a good resource of information about a community, however, they are not to scale.

5. *Field team selection and training*

Consider the following team composition:

- Project Manager to oversee the planning and implementation of activities;
- GIS Field Manager(s) to plan and oversee field operations;
- Data Collectors with a field team structure to support organized data collection and coordination, preferably with basic computer skills, such as Microsoft Word, Excel and internet search;
- Community Liaison for community relations

6. *Form evaluation method preparation*

Review the questionnaire, methods, tools, and team composition, including roles and responsibilities with the whole team.

Conduct several mock-up sessions to test the above and make necessary adjustments prior going to the field for data collection.

7. Awareness raising campaign

Pre project sensitization and communication with key community leaders is key. Community Liaison and, preferably, community mappers as well should come from the community where the mapping activities take place. They should spend enough time with leaders, elders, women, and other demographics to ensure beneficiaries are aware of the project aims and participate willingly.

Field work

1. Reconnaissance mission, understanding the environment

Field activities should be preceded by a reconnaissance mission undertaken by a GIS professional. This will allow the team to understand the size of the area, develop a more accurate estimate of time and resources required, and develop a communication and safety plan to conduct fieldwork.

Alternative communication options in low connectivity areas are satellite phones and VHF radio. The field team could establish a central communications point, such as a market with mobile connectivity, to facilitate communications outside of the field (in case of emergency such as a stuck vehicle, an injury, or a conflict).

It is important to talk about the areas of existing conflict and to indicate them for the purpose of documentation and to preparation of a safety plan for fieldwork. Existing topographic maps or satellite imagery can be used to indicate the areas in question.

Community land mapping is a technical and politically sensitive undertaking and should be supported by GIS and surveying professionals if possible. GIS and surveying professionals can explain the different tools and methods used in community mapping, mitigate risks and liaise with other stakeholders to ensure the benefits of the exercise outweigh these risks.

2. Field work operations

a. Interview

Conduct an interview using mobile or paper based questionnaire. During the interview, record:

- Information on the owner, such as name, ID, date of birth, mobile number, email, sex.
- Physical address of the plot, such as county, sub-county, sub-location, postal address.
- Information on land, such as plot name, reported acreage, land use, resources, and assets.
- Information on property right, such as availability of title deed, type of title deed (owner, leaseholder, tenant), sole ownership or shared, other persons with rights to land, date of purchase, any disputes on land, any other difficulties.
- Information on easement and right of way.
- Boundary points (% accurate as compared to surveyor)
- Acreage (% accurate as compared to surveyor)
- Pictures of land and boundary points
- Pictures of owners, their id’s, etc.
- Any other remarks.

b. Sketch map

After the interview, accompany the owner on foot to all boundary points of the parcel and drew a sketch map. In many cases, this information, coupled with measurements collected with measuring tape, can be sufficient in rural areas, even by the surveyor's standards.

c. Recording results

After the sketch is complete, the mapper uses either an off-the-shelf GPS or a mobile tool or combination of both to collect the boundary points of the parcel to which he/she then attaches all the attribute information gathered during the interview.

d. Saving and sharing

If using paper for data collection, type the data into excel and share it. If using a mobile phone, save the data locally, connect to Internet, if possible, and upload the data into the cloud, If using GPS unit, transfer the data into the computer, save it locally and upload it into the cloud.

e. Evaluating data collected

Review the data collected with community members and facilitate their acceptance of the data.

Post field work data management

1. Post-fieldwork data processing

Depending on the method and tool of data collection, data has to be processed. This can be achieved with any GIS software and it usually requires greater skillset.

2. Map/data dissemination

Data from the field should be turned into visual, digital representations of properties as they denote actual size of parcels and are necessary for official documentation.

3. Community feedback

Gathered information, including maps should be brought back to the communities for verification.

4. Present the data to the government officials

Gathered information should be shared with government officials, verified and reconciled.

Putting Community and rights on the map in southern Kenya