P. Schøning, J.B.M. Apuuli, E. Menyha and E.S.K. Muwanga-Zake

Handheld GPS Equipment for Agricultural Statistics Surveys

Experiments on area-measurements done during fieldwork for the Uganda Pilot Census of Agriculture, 2003

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Brudd i den loddrette serien	Break in the homogeneity of a vertical series	—
Brudd i den vannrette serien	Break in the homogeneity of a horizontal series	|
Desimalskilletegn	Decimal punctuation mark	,(.)

Abstract

P. Schøning, J.B.M. Apuuli, E. Menyha and E.S.K. Muwanga-Zake

Handheld GPS Equipment for Agricultural Statistics Surveys
Experiments on Area-Measurement and Geo-referencing of holdings done during Fieldwork for the Uganda Pilot Census of Agriculture, 2003

Reports 2005/29 • Statistics Norway 2005

Uganda Bureau of Statistics and Statistics Norway staff jointly conducted fieldwork in Uganda 2003 experimenting with simple handheld Geographical Positioning System (GPS) tools for determination of agricultural holding areas and geo-referencing of holdings. NORAD funded this exercise under the "Support to Strengthen Agricultural Statistics" Program 2002-2005. The objective of the exercise was to test out the feasibility of using a hand held Global Positioning System (GPS) tool as an alternative instrument for area measurement during agricultural fieldwork in Uganda. The experiment was conducted as a part of the Pilot Agricultural Census (PCA). More than 900 holdings distributed in 10 districts of Uganda were visited and parcel and crop plot areas where measured using several methods. Therefore a substantial number of observations are available for comparative analyses. From the PCA there are a total of 430 observations where areas of parcels were measured both with GPS and by traversing (tape & compass). Tape and compass measurements is regarded as the most accurate observation of the ground truth taken during the experiment. However, a paired T-test of this set of observations reveals that there is minor difference between the results of GPS use compared to Traversing concerning parcels measured during the PCA fieldwork 2003. The same conclusion was also drawn when measurement of the smaller crop plot areas were compared. For both parcel and crop plot areas, the farmers and enumerator's eye-estimates were found not to be reliable. A subset of 191 observations about time use on holdings where both GPS measurements and traversing with tape and compass was conducted. It can be observed that the average time use per holding for traversing was as much as 3 hours and 23 minutes or 3.5 times as much as when GPS was used. The price of high quality tape and compass equipment was, at the time of the experiment, approximately 25 USD and 100 USD (compass including jacket) respectively. In addition a fairly expensive programmable calculator is necessary to calculate areas captured by traversing. The total price is therefore not so different from the price of the simple handheld GPS tool used. However, battery costs are high for GPS use, while almost neglectable for traditional traversing.

Three recommendations from this study are presented as follows: Recommendations 1 - findings from the PCA indicate that there is potential to use relatively cheap Global Positioning System (GPS) equipment for measuring of area and for geo-referencing of holdings in the context of agricultural statistics. Recommendation 2 - GPS measurement without additional equipment for adjustments of signals and/or improved antenna proves to give some variation in the measured area. Therefore, repeated measurement and calculation of an average of the same area as well as further improvement of tools set-up and methods, is recommended. Recommendation 3 - Training of fieldworkers in the technical use of the GPS, including how to set it up correctly, is crucial.

Acknowledgement: We are grateful to NORAD for its funding of the SSASP project and thereby enabling for improvement of the agricultural statistics in Uganda by further development of methods and introduction of new technology. Especially thanks to all the Ugandan farmers, fieldworkers and entry staff contributing to this exercise.

Contents

1. Summary

One of the most important factors for production of crop growing, raising livestock or any other farming activity, is land. The pattern of land-use usually varies by seasons or by different regions of the country. Thus, accurate data on area used for agricultural purposes is an important aspect of agricultural planning.

Experience from the Uganda Agricultural Censuses in 1963/65 and 1990/91, indicates that farmers area estimates are unreliable, and that the traditional method of measuring areas by measuring tape (or wheel) combined with compass use and traversing the perimeter of the selected area is a very time consuming method.

On this background it was decided to look for an alternative method for area measurement by introducing the hand held Global Positioning System (GPS) tool for fieldwork in Uganda. This was done under the "Support to Strengthen Agricultural Statistics Project" (SSASP), conducted jointly by the Uganda Bureau of Statistics (UBOS) and Statistics Norway (SN) in the period from 2002 to 2005.

The SASSP program has several components. However first priority in 2003 was to plan and conduct a Pilot Census of Agriculture (PCA) in order to develop methodologies, and test out logistics in preparation for a Uganda Census of Agriculture and Livestock (UCAL) slated for 2004 and/or other agricultural surveys in the pipeline.

During the PCA, 900 holdings distributed in 10 districts were interviewed and parcel and crop plot areas where measured using several methods. PCA is therefore a source for substantial number of empiric observations.

This paper discusses experience of use of different tools and methods for area measurement based on the fieldwork conducted during the PCA 2003 in Uganda. The findings indicate that there is potential to use relatively cheap Global Positioning System (GPS) equipment for measuring of area and for geo-referencing of holdings in the context of agricultural statistics. However, experience from the fieldwork shows that there is need for thorough training of field staff before GPS tool can be efficiently used. More studies are also recommended concerning the variability and consistency of the measurements taken, especially where tree cover and/or hilly areas introduce "shadow" and projection problems.

This report is produced jointly by Statistics Norway Division for Development Cooperation and Uganda Bureau of Statistics Staff under the program "Support to Strengthen Agricultural Statistics Project" (SSASP)" 2002-2005.

2. Background

2.1. Background for Agricultural Statistics in Uganda

The Uganda Government has taken strategic decisions to make poverty eradication the over-riding objective of agricultural development. Through the Plan for Modernization of Agriculture (PMA) the objective is amongst others to give priority to agriculture as the engine for economic growth and poverty eradication as well as to transform small holding farmers from subsistence to producing for the market.

In order to accelerate growth and to reduce poverty, the Government of Uganda has decided to modernize the agricultural sector and introduced the Plan for Modernization of Agriculture (PMA). An obvious precondition for implementation of PMA is to have in place tools for monitoring and evaluating the status and possible changes in the agricultural sector over time. However, national and international assessment reveals that the existing agricultural statistics system in Uganda is weak, vulnerable and not able to meet modern user needs. Improvement or further development of the Uganda Agricultural Statistical system is therefore necessary.

The Uganda Bureau of Statistics (UBOS) in cooperation with the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), is under the umbrella of the Plan for Modernization of Agriculture (PMA) conducting a three years project "Support to Strengthen Agricultural Statistics Project" (SSASP) during the period from 2002 to 2005. The project has a budget of 18.5 mill. NOK funded by the Royal Government of Norway. UBOS is the implementing agency, while MAAIF is the cooperating agency in the project. The agreement and project document on SSASP, was signed by representatives of the Government of the Kingdom of Norway and the Government of the Republic of Uganda on November 30, 2001.

According to Article 1 of the agreement signed, an institutional cooperation between UBOS and Statistics Norway (SN) was agreed for implementation of SSASP.

The SASSP program has several components. However first priority in 2003 was to plan and conduct a Pilot Census of Agriculture (PCA) in order to develop methodologies, and test out logistics in preparation for a Uganda Census of Agriculture and Livestock (UCAL) slated for 2004 and/or other agricultural surveys in the pipeline.

This is the background for the "Systems for Strengthening Agricultural Statistics Project" (SSASP), a twinning project between the Uganda Bureau of Statistics (UBOS) and Statistics Norway (SN). The overall objective of the SSASP is to strengthen the ability of UBOS to identify the needs and then to produce and disseminate agricultural statistics information to national and international users. Baseline statistics and tools for monitoring effects of the implementation of the PMA are priority objectives.

2.2. Background for testing of GPS as a tool for area measurement

Reliable estimation of annual production of food crops and other agricultural commodities are very important, for a developing country such as Uganda, which is making serious efforts to tackle the problem of feeding her population, diversifying her export crops and, thus, raising the living standards of her people. Unfortunately, there have been major methodological problems in the estimation of crop production in developing countries, particularly in Africa.

One of the most important factors for production used in growing crops, raising livestock or any other farming activity, is land. The pattern of land-use usually varies by seasons or by different regions of the country. Thus, accurate data on area used for agricultural purposes is an important aspect of agricultural planning.

Total land operated by the holder (i.e. the agricultural holding) is a crucial variable for the analysis of agricultural data. The area of a holding may vary from time to time. A holder may sell or leave part of his/her holding or he/she may buy or rent from others.

At any time the holder has the option to fully or partially utilize the holding. Thus the proportion of the holding under crop also varies from season to season or from year to year. Since production can be estimated as a product of Yield and Area, there is definite relationship between area planted and amount of crop harvested. The product can easily be computed in the case crops are grown in pure stand. The problem is however more complex if crops are in mixed stand.

Agriculture is indeed an area-based industry. Crop and forest products is directly linked to area size and the area quality. Even highly industrialized “zero grazing” models for animal rearing and piggeries are in the end depending on area based crop production. Thus accurate and timely information of agricultural areas is one of the very core variables in all agricultural statistical censuses and surveys.

Hence area measurement for use in traditional agricultural statistics has a twofold objective:

- To determine the structural changes of the agricultural holdings i.e. changes in total area size of the holding, size of the different land use categories and also to follow possible fragmentation or aggregation of farmland.
- To enable for determination of the potential and actual agricultural production by calculation of total crop production as a function of yield and area

In Uganda there is no complete cadastral map or land register that includes information about holding areas. Experience from previous surveys and censuses also reveals that most of the holders in rural Uganda are not able to accurately determine the size of their land in useable quantitative units. As a consequence, all information about size of land has to be collected from scratch by measuring.

Experience from area measurement during the Uganda Agricultural Censuses in 1963/65 and 1990/91, indicates that the measuring of areas by measuring tape (or wheel) combined with compass use and traversing the perimeter of the selected area is a fairly accurate but very time consuming method. The accuracy of this method depends on the enumerators capacity to read the compass and tape measures and also to which extent approximation to the actual shape of the parcel or plot has to be done – the so called “give and take approach”. Also the cost for instruments like high quality compass, measuring tapes and programmable calculators are considerable.

On this background it was decided to look for an alternative method for area measurement by introducing the hand held Global Positioning System (GPS) tool for fieldwork in Uganda.

Use of GPS during fieldwork also opens up for geo referencing of agricultural holdings. This becomes relevant in the context of agricultural statistics since Geographical Information Systems and Tools (GIS/GIT) is widely introduced in research institutions and civil administration planning units. Exact positioning of holding center and even of parcels and crop-plots can be combined with other geo referenced thematic information and digital base maps for spatial analyses and planning.

3. Pretest of GPS in Masaka District June/July 2002

Experiments with alternative methods for area measurements were introduced already as the pre test for the Uganda Census of Agriculture and Livestock was conducted in Masaka district June/July 2002.

As a direct consequence, two hand held GPS of the type Magellan Meridian (www.magellan.com) was used on experimental basis in order for area calculation of crop-plots and parcels as well as for geo-referencing of the holding during the pretest.

An application for automatic calculation of areas based on recording the start position and the track-log of the perimeters was introduced. The software was downloaded to the GPS tool by the Norwegian supplier specially for this exercise.

The GPS equipment is in principle a high precision digital watch combined with a signal receiver. It finds longitudes and latitudes on the earth's surface. The geographical position is found by continuously measuring the time signals take from satellites in the sky to the GPS tool on the earth surface. An obvious advantage that the GPS tool has compared to the traversing with tape&compass, is that the perimeter of the area can be followed fairly quickly, accurately and completely.

The findings of the pretest was that, compared to accurate but time consuming traversing of the same areas using compass and measuring tape, the average of the GPS registrations seemed to be of promising accuracy. However, the variation in the repeated measurements caused some concern at this stage. GPS based calculation of areas was during the pretest done both by reading results from the device display directly and in addition by downloading the track-log polygons to a GIS software for storage, mapping and area calculations on a lap-top.

The registration of the holdings representation point co-ordinates caused no serious problems during the pre-test fieldwork. Several of the UBOS staff and enumerators involved had the opportunity to learn how to use the GPS tool.

4. Further experimentation and fine tuning of GPS setup

GPS tools in sufficient numbers for use in the PCA turned out to be available in UBOS. These tools were initially procured and used in an effort to allocate coordinates to all units in the Uganda Business Register.

The tools available were of the type Garmin 12 or Garmin 12XL. Most of these tools already contained the necessary software to calculate areas. Information for upgrading for area calculation software for those tools were this function was missing, was downloaded from the Garmin home pages (www.garmin.com).

In cooperation with experts from the National Biomass Study Project and geographers within UBOS, the instruments setup were optimized for area registrations i.e. the interval for registration recoded to the track-log was minimized and a suitable projection and co-ordinate system was agreed. The latter also to ensure for comparability with already existing digital thematic maps relevant for agriculture presentations and GIS analyses. It was agreed to use the following setup specifications:

MAIN MENUE → Setup menu → Navigation:
Position frmt: hddd.ddddd °
Map Datum: WGS 84
Units: Metric
Heading: Auto E001° Degrees

MAP WINDOW
0.3 / PAN / OPT

TRACK SETUP
Record: Wrap
Method: Time interval 00:00:10
Track setup→Calc area
Units: sq mt

During this preparatory experimentation the possibility for downloading vector data for each parcel and plot perimeter was discussed and tested. For practical reasons this approach was not further followed up. Recording of parcel and plots polygons as vector data would require advanced and expensive systems for transferring large amounts of geographical data from the fieldwork into UBOS storing and processing facilities. In addition, the accuracy of the shape of the polygons registered with a handheld GPS without any adjustments facilities or access to WAAS techniques, would not fulfill technical requirements for use as cadastral maps. Finally cadastral mapping was anyway regarded as being outside the scope of a census of agriculture.

During October/November 2003 studies of accuracy and variation of the results of area measuring based on the use of GPS was carried out. Initial studies with repeated GPS measuring shows a reasonable variation around a true value accurately measured by tape and compass to 483 m^2 illustrated as follows:

Table 4.1. Plot area (m2) measured by GPS. January 2003

		Statistics	Std. Error
Number of observations		22	
Mean		474.14	5.73
95% Confidence	Lower Bound	462.22	
Interval for Mean	Upper Bound	486.06	
Median		482.50	
Variance		722.89	
Std. Deviation		26.89	
Minimum		407.00	
Maximum		510.00	
Range		103.00	

As a result of the pretest and the following experimentation and fine-tuning, it was decided to go on and to expand the experimentation with the GPS tool during the PCA. The approach agreed for the PCA was to traverse the perimeter of the selected areas with the GPS, conduct readings of results of position and areas directly from the GPS display and finally recording the data into traditional statistical questionnaires.

5. Testing of GPS during the Pilot Census of Agriculture, 2003

5.1. Experimental design for measurement of areas

The land area measured per holding selected for the PCA was limited to the part of the holding that was located within the selected EA and included:

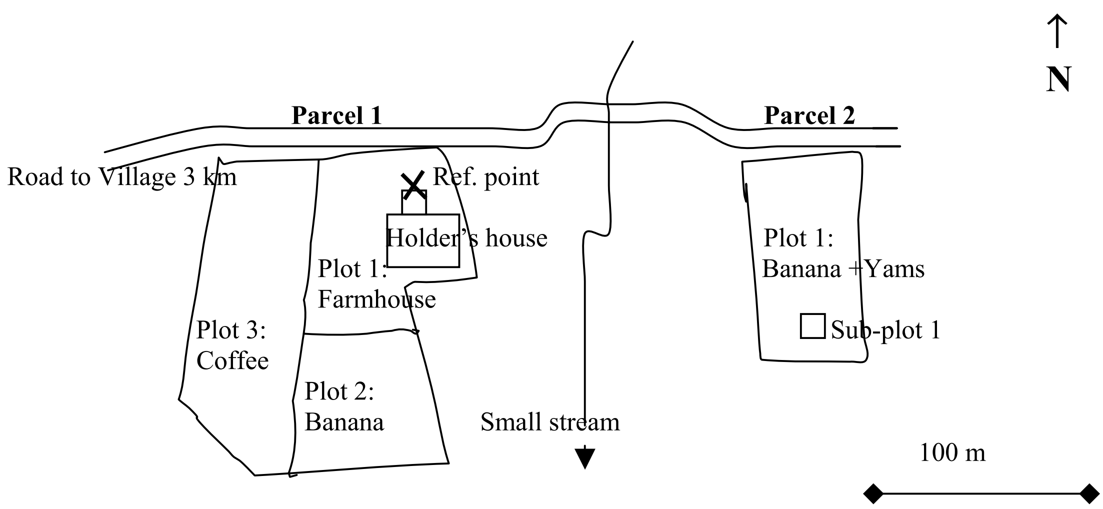
- The total area of the holding.
- The area of agricultural parcels and plots under various crops.
- Pasture land.

The experimental design of the PCA provided four approaches to area estimation for three groups of holdings within each Enumeration Area (EA). Each EA had a total of 15 holdings selected, so each of the three randomly selected groups had 5 holdings. The experimental design for area measurements was as follows:

1. Holders'/respondents' eye estimates of parcel and crop plot area was recorded on the 5 selected holdings in Group I.
2. Enumerators' eye estimates of parcel and plot area was recorded on the 10 selected holdings in Groups II and III.
3. Measurements using compass and measuring tapes was recorded on the 5 selected holdings in Group I.
4. Measurements by use of GPS equipment was recorded for all the 15 holdings in the EA i.e. for all the Groups I-III.

A sketch map of parcels and plots for each of the fifteen holdings in the EA was made in order both to plan the fieldwork, and to enable for finding back to the holding if later visits should be necessary.

Figure 5.1. The concept of parcels and crop-plots on agricultural holdings in Uganda



The area measurements and/or estimates for both parcels and plots were carried out in the following sequence:

- While walking around the holding to decide on the parcel boundaries and the number of plots to be found on the parcel, the holder's/respondent's area estimate were to be recorded in the appropriate form for the five selected holdings for Group I.
- The Enumerator would make his eye estimates and record it on the appropriate forms for the ten selected holdings in Groups II and III.
- The Enumerator would take measurements using compass and measuring tape (traversing) on five selected holdings in Group I, and record the measured results (meters and degrees) for each of the sides in the parcel/plot that was measured. Results were then recorded (bearings and lengths). Thereafter, the Enumerator would calculate the measured area and the closing error using the programmable calculator and record the final results.
- The Enumerator would do the area measurement using the GPS equipment for all parcels and plots in Group I –III and record it in the same forms.
- Finally the Supervisor and/or the team from UBOS/MAAIF crosschecked some selected parcels and plots by measuring, using GPS equipment.
- The Holders'/Respondents' eye-estimates were made on different holdings to ensure independence of the two. Further, the actual measurements were to be carried out after the eye-estimates again to ensure independence. In both cases the eye-estimates would not be affected.

5.2. Lessons learned from the PCA

The way the GPS equipment was set up for the PCA, the area of each parcel and plot was calculated directly in square meters. Therefore, the value had to be converted to hectares (by dividing by 10,000) with two decimal places before information could be recorded in the appropriate questionnaire. Some enumerators had problems converting from Square Meters to Hectares. Others had recorded the values in square meters directly on the forms and this caused some confusion in the data entry/data cleaning process.

Using a hand held GPS-tool is basically not much different from operating a cellular phone and thus possible to allow for non-experts use. Enumerators and supervisors were instructed in the use of GPS-tool during the training course just before the PCA fieldwork started.

During the fieldwork it turned out to be necessary to repeat and further drill the routines for using the GPS. Unfortunate changes of the setup of the instruments accidentally occurred and had to be corrected. However, in the end most of the enumerators managed to record both areas and coordinates according to the instructions.

Since the GPS is fast and easy to use compared to traversing with tape and compass, in some cases the enumerators only conducted GPS measurements and in spite of their instructions they did not follow up with the requested but cumbersome traversing of the same plot. It is also assumed that using the "high tech" GPS adds importance and status to the enumerator's work as he/she visits the holders.

During area measurement the experience was that positioning from between 5 to 8 satellites for each observation were received. The expected accuracy when using a hand held GPS-tool without any corrections based on additional fixed ground stations or WAAS techniques is better than +/- 15 meters. This accuracy is acceptable when the objective is to geo-reference the holding for statistical use.

During the PCA fieldwork problems were found with using the GPS-tools on plots and parcels where the tree canopy cover is dense. In addition, there were problems with area measuring in very steep terrains due to the difference between actual area and horizontal projections. Also struggling with some "shadow" effect when receiving of signals from satellites in hilly terrain caused problems. A possible improvement will be to equip the GPS-tool with an external antenna device when used under extreme conditions. This is possible for the GARMIN 12XL tool.

5.3. Results from use of GPS and traversing during the PCA

The experimental design of the PCA allowed the comparison of the results of area measured with GPS equipment, by traversing with tape and compass and even by eye estimates by the holders and enumerators on a large number of holdings and in different kind of topographic and vegetation cover conditions.

Initially problems with the accuracy were expected when the objective was to measure the area of parcels and plots. Experience on the ground, as illustrated in the table 4.1, was however more positive. Basically the results of GPS measurements of areas reveal variances around the assumed most correct area figure i.e. the figure based on accurate traversing.

5.3.1. Comparative study of measurement method for Parcels

The total dataset where the information about holder's and enumerator's estimates are linked to information about parcels measured with tape & compass and GPS comprises 1 572 parcels of which:

- 1 257 were measured by GPS equipment
- 453 were measured by traversing (tape & compass)
- 599 parcels were estimated by the holder
- 990 parcel areas were estimated by the enumerator.

There were 430 observations where areas of parcels were measured both with GPS and by traversing (tape & compass). A paired T-test (see figure 5.2 and table 5.1-5.3) of this set of observations reveals that there is no significant difference between the results of the two methods concerning parcels measured during the PCA fieldwork 2003.

Figure 5.2. Comparison of area measured by GPS and by traversing. Parcels. PCA 2003

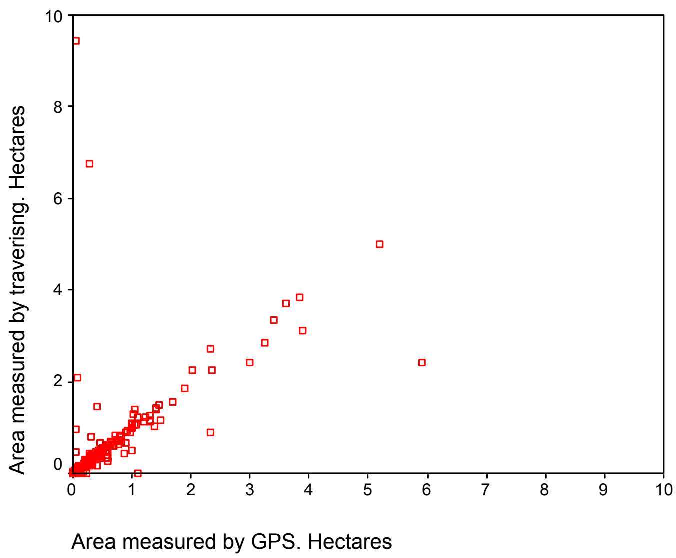


Table 5.1. Paired Samples Statistics of parcel areas

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	AREA_TRAVERSING	0.3757	430	0.77711	.03748
	AREA_GPS	0.3541	430	0.63427	.03059

Table 5.2 Paired Samples Correlations of parcel areas

		N	Correlation	Sig.
Pair 1	AREA_TRAVERSING & AREA_GPS	430	0.653	0.000

Table 5.3. Paired Samples Test of parcel areas

		Paired Differences					T	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	AREA_TRAVERSING & AREA_GPS	0.0215	0.60195	0.02903	-0.0355	0.0786	0.742	429	0.459

5.3.2. Comparative study of measurement method for Plots

The total dataset where the information about holder's and enumerator's plot area estimates as well as crop information are linked to information about plots measured with tape & compass and GPS comprises 3,580 plots of which 3,086 plots are measured by GPS (GPS area >=0.00), 1,086 plots are measured by traversing (tape & compass area >=0.00), 1 028 plots are estimated by the holder and finally 2 341 plot areas are estimated by the enumerator.

A total of 1,004 plots were found where area is both measured by the GPS tool and by Traversing (measured area both for GPS and Traversing >=0). The area size of most of the measured plots is very small and in order to reveal possible differences between measurement of small and larger plots during the statistical testing, the dataset for plots was divided into 2 strata; *Stratum 1* with plot areas at least 0.5 hectares (N=70) and *Stratum 2* with plot area size less than 0.5 hectares (N=934). Thereafter a paired T-test comparing the areas obtained by traversing and use of GPS tool was conducted for the two strata of plot area size. The results of these T-tests are presented in Table 5.4-5.6.

Table 5.4. Paired Samples Statistics of Plot Areas

		Mean	N	Std. Deviation	Std. Error Mean
Stratum 1	Traversing	8.9251	70	14.37497	1.71814
	GPS	7.8983	70	14.29725	1.70885
Stratum 2	Traversing	0.1441	934	0.57584	0.01884
	GPS	0.0894	934	0.09383	0.00307

Table 5.5. Paired Samples Correlations of Plot Areas

	N	Correlation	Sig.
Stratum 1	70	0.897	0.000
Stratum 2	934	0.121	0.000

Table 5.6. Paired samples Test of Plot Areas

	Paired differences					T	Df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Stratum 1	1.0269	6.49338	0.77611	-0.5214	2.5752	1.323	69	0.190
Stratum 2	0.0547	0.57209	0.01872	0.0180	0.0914	2.922	933	0.004

The results from the paired T-test above indicates that traversing of the plots that are at more than 0.5 hectares, gives a slightly larger area per plot compared to the same plot area measured by GPS equipment. This tendency seems to be the same when plots with area size less than 0.5 hectares are measured. However, since the questionnaire only allowed for filling in of hectares with 2 decimals, this size group of small plots may have been disturbed by rounding-routines for the smallest areas measured i.e. those plot areas that were less than 0.01 hectares but rounded up and recorded as being equal to 0.01 hectares by the Enumerators.

5.4. Results of Comparison of Time use during PCA

Time use for the different measurement methods was recorded by the enumerator during the fieldwork of the PCA. For all observations recorded, the average time use for traversing with tape and compass was three times as long per holding as when GPS equipment was used (table 5.7-5.9).

A subset of all observations was selected in order to compare observations about time use on those holdings where both GPS measurements and traversing with tape and compass was conducted. A test for this subset of 191 holdings reveals that time use for traversing was as much as 3 hours and 23 minutes or 3.5 times as much as when GPS was used (Table 5.9). Therefore it can be concluded the GPS is a far more time-efficient method/tool than the tape and compass measured in terms of average time use per holding.

Table 5.7. Observations of time used by method of area measurement. PCA 2003

	Traversing	GPS use	Enumerator's estimate
Valid	302	538	448
Missing	476	240	330

Table 5.8. Time use by method of area measurement. PCA 2003. Minutes

	Traversing	GPS use	Enumerators estimate
Mean	153.9	55.6	46.1
Median	97.0	48.0	37.5

Table 5.9. Comparison of time used for traversing and GPS. PCA 2003

	Mean minutes used	Comparable observations (N)	Standard. Deviation	Standard error for the mean
Traversing	203.1	191	185.4	13.4
GPS use	57.8	191	34.1	2.5

5.5. Comparison of costs of instruments

Even simple handheld GPS tools are relative expensive tools. The GPS model used in the PCA was a Garmin 12 channel receiver with an approximate price of 150 USD per unit (2003 prices). During the PCA fieldwork, 3 enumerators shared two GPS tools.

The use of batteries turned out to be high as it was agreed to change batteries when approximately 2/3 of the energy was used. Since each GPS uses 4 high quality AA batteries, the costs for power supply was considerable. The recommended batteries cost an equivalent of US$1.25 per pair compared to the more commonly used ones, which cost about US Cents 25. Use of re-chargeable batteries may reduce the costs. The enumerators were instructed to switch off the equipment whenever not in use. It is however, not easy to know how well they followed this instruction.

For further work it should be experimented with rechargeable batteries as a possible more cost efficient option. However not all areas in Uganda have stable power supply and recharging can give some logistical problems.

Two GPS device were lost during the project period due to unfortunate civil unrest in the enumeration areas. Such losses and cost will have to be expected to occur even more frequently in a full census since all districts shall be included.

The price of high quality tape and compass equipment is approximately 25 USD and 100 USD (compass including jacket) respectively. In addition a fairly expensive programmable calculator is necessary to calculate areas captured by traversing. The total price is therefore not so different from the price of a GPS tool. On the other hand, battery costs are near zero for tape and compass.

6. Conclusions

The results from the PCA indicate that the area measurements by the GPS equipment and those by the compass and tape are very close – for parcel areas there were no statistically significant difference between the results of the two methods. Farmer's eye-estimates of area size both for parcels and plots and seem to overestimate the size of the areas compared to values obtained from use of GPS and traversing technique. Considering that the GPS equipment is much faster and that costs are fairly the same as to those of traversing, this indicates that there is a potential for the GPS equipment for agricultural area measurements. However, efforts need to be made for cheaper GPS equipment and running costs or at least more efficient use. There is also need for more thorough training of field staff. Finally, more study is required on the variability and consistency of the equipment under more scientifically designed and closely supervised conditions. Special studies concerning effects of steep slopes and under tree and cloud cover should also be conducted.

7. Further work and new possibilities for statistics

Combination of digital thematic maps, digital administrative boundaries and geo-referenced statistical information opens for spatial analyses of data. However, before such data can be used in Geographical Information Systems (GIS), a long process of data capture, geo-referencing/geo-coding, scanning and digitalization is required. Since geographical information will be found in different organizations in Uganda, it is crucial for common use to agree upon standards and formats.

By introducing geo referencing (coordinates) and geo-coding (administrative division unit code) to statistical information of agricultural holdings sampled during survey and censuses and at the same time introduce similar coding for business and industry surveys/ listings, new possibilities spatial analyses of data occurs. The statistical information can also be combined with other sources of digitalized geographial data such as thematic maps available at the Uganda National Biomass Study including digital main road net, water courses, land cover classes etc.

Annex A

List of abbreviations

FAS	Framework of Agricultural Statistics
GIS	Geographical Information System
GIT	Geographical Information Technology
GPS	Global Positioning System
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
NOK	Norske Kroner
NORAD	Norwegian Agency for Development Cooperation
PCA	Pilot Census of Agriculture
SN	Statistics Norway/Statistisk sentralbyrå
SSASP	Support to Strengthen Agricultural Statistics
UBOS	Uganda Bureau of Statistics
UCAL	Uganda Census of Agriculture and Livestock
USD	United Stated Dollars
WAAS	Wide Area Augmentation System

Copy of selected questionnaires from PASS Form 3 Area Characteristics and Measurement

Annex B

3.3.2 Characteristics for all parcels of agricultural land operated by the holder the current agricultural season located *within* the Enumeration Area and *elsewhere*.

23. Specify all agricultural land by parcel (incl. land for farmhouse, stables, storehouses etc) used by the holder within **the actual Enumeration Area and** elsewhere**. Start with the parcels** within **the Enumeration Area and list possible parcels located** elsewhere **at the end as follows:**

Parcel no	Parcel name	Geo-graphical location of the parcel (code)	Land tenure system (code)	Total size of parcel			Rental arrange-ments for areas rented from others (code)	Parcel operator (code)	Soil erosion		Pests and Diseases		
				Holder's area estimate		Enumerator's area estimate (Hectares)			Is there a problem? 1=yes 2=no	If yes, why? (code)	Was there a problem on the parcel last agric-ultural season? 1=yes 2=no	If yes, why? (code)	When did it occur? 1=Pre harvest 2=Post harvest)
				Measur-ing unit (code)	Area								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14
1					☐☐☐.☐☐	☐☐☐.☐☐							
2					☐☐☐.☐☐	☐☐☐.☐☐							
3					☐☐☐.☐☐	☐☐☐.☐☐							
4					☐☐☐.☐☐	☐☐☐.☐☐							
5					☐☐☐.☐☐	☐☐☐.☐☐							

Codes for Column 3:
1=Within the E.A.
2=Outside the E.A but within the same Parish from extension
3=Outside the Parish but within the Sub-County
4=Elsewhere in the District

Codes for Col. 4:
1=Freehold (Mailo)
2=Unreg. Freehold (Mailo)
3=Leasehold
4=Customary (Public)
5=Customary (Freehold.)
6=Squatter
…………………..
7=Other, specify

Codes for Col. 5:
1=Hectare
2=Acre
3=Mwiigo (square)
4=Other local unit
5=Not applicable

Codes for Col. 8:
1=Share cropping
2=Cash cropping
3=Share crop + cash
4=Other
5=Other relatives

Codes for Col. 9:
1=Holder
2=Spouse
3=Son/daughter
4=Father/mother
5=Grass burning
6=Hired manager
7=Non-relative

Codes for Col. 11:
1=No terracing
2=Poor Agriculture practice
3=Overgrazing
4=Deforestation
5=No soil fertility initiatives
6=Other, specify …………………..

Codes for Col 13:
1=No control measures
2=Lack of assistance
3=Farmer's failed to identify the diseases/pests
4=Lack of resources/un-affordability
5=Other, specify

If other local area measuring unit is used:

24. Specify term: …………………….

25. Specify m² equivalent: ……………..

3.3.3 Plot Characteristics for parcels and plots *within the Enumeration Area. Holder's yield forecast.*

26. Specify all crop plots by agricultural parcel (incl. land for farmhouse, stables, storehouses etc) used (i.e. excl. parcels rented out to others) by the holder within the actual Enumeration Area. What is the holder's forecast for total harvest from the plot this agricultural season?

Parcel no	Plot no	Total size of plot			Use Code	Crop 1				Crop 2		Crop 3		Crop 4		*Who decides on the use of proceeds from the plot?* (Code)	*Was it the same crop stand on this plot last agricultural season?* Yes=1 No=2
		Holder's area estimate		Enumerator's area estimate (Hectares)		Type Code	Cover %	Holders harvest forecast		Type Code	Cover %	Type Code	Cover %	Type Code	Cover %		
		Measuring unit (code)	Area					Unit of measure (code)	No of units								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)

Codes for Col. 3:
1=Hectare
2=Acre
3=Mwiigo (square)
4=Other local unit

Codes for Col . 6:
1=Pure stand
2=Mixed stand
3=Fallow
4=Farm houses etc.
5=Other, specify ……………………………………

Codes for Col. 7,9, 11, 13, and 15:
See Enumerators manual

Codes for Col 17:
1=Mainly husband
2=Mainly wife
3=Husband and wife jointly
4=Children
5=Other, specify …………………………

If other local area measuring unit is used:

27. Specify term: ……………………

28. Specify m^2 equivalent: ....

3.3.4 Area measurement of parcel

29. Measure the area of each agricultural parcel operated by the holder within **the Enumeration Area. The area for farmhouse and other farm/holding building is measured as a parcel (and/or a plot). Use an additional notebook for calculations and drafts, and fill in final figures in the form. Calculate and fill in the areas measured by tape & compass and by GPS.**

Parcel no	Measured by tape & compass															GPS
	Observations	Parcel side no.												Area (Hectares) 2 decimals	c.e. %	Area (Hectares) 2 decimals
		1	2	3	4	5	6	7	8	9	10	11	12			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
	F. B. (deg)													☐☐☐.☐☐		☐☐☐.☐☐
	B. B. (deg)															
	Diff. (deg)															
	Side length (m)															
	F. B. (deg)													☐☐☐.☐☐		☐☐☐.☐☐
	B. B. (deg)															
	Diff. (deg)															
	Side length (m)															
	F. B. (deg)													☐☐☐.☐☐		☐☐☐.☐☐
	B. B. (deg)															
	Diff. (deg)															
	Side length (m)															
	F. B. (deg)													☐☐☐.☐☐		☐☐☐.☐☐
	B. B. (deg)															
	Diff. (deg)															
	Side length (m)															
	F. B. (deg)													☐☐☐.☐☐		☐☐☐.☐☐
	B. B. (deg)															
	Diff. (deg)															
	Side length (m)															

3.3.5 Area measurement of plots

30. Measure area of each crop plot on an agricultural parcel operated by the holder *within* the Enumeration Area. The area for farmhouse and other farm/holding buildings is measured as a separate plot (or parcel). Use an additional notebook for calculations and drafts and fill in final figures in the form. Calculate and fill inn the areas measured by tape & compass and by GPS.

Parcel no	Plot No	Measured by tape & compass															GPS
		Observations	Plot side no.												Area (Hectares with 2 decimals)	c.e. %	Area (Hectares with 2 decimals)
			1	2	3	4	5	6	7	8	9	10	11	12			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
		F. B. (deg)															
		B. B. (deg)															
		Diff. (deg)															
		Side length (m)													□□□.□□		□□□.□□
		F. B. (deg)															
		B. B. (deg)															
		Diff. (deg)															
		Side length (m)													□□□.□□		□□□.□□
		F. B. (deg)															
		B. B. (deg)															
		Diff. (deg)															
		Side length (m)													□□□.□□		□□□.□□
		F. B. (deg)															
		B. B. (deg)															
		Diff. (deg)															
		Side length (m)													□□□.□□		□□□.□□

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