GPS Equipment for Agricultural Statistics Surveys - Lessons Learned from Fieldwork in Uganda

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Summary

1. 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 Uganda. Thus, accurate data on area used for agricultural purposes is an important aspect of agricultural planning.

2. In Uganda there is unfortunately no complete set of cadastral maps and/or land registers from which area information can easily be derived. Experience from previous agricultural censuses and surveys also reveals that most rural holders in Uganda are not able to accurately determine the size of their land in quantitative terms that can be used in statistics. Therefore, when statistical surveys and censuses are conducted, any information on the size of land has to be by some kind of measurement.

3. This paper discusses results from a Pilot Census of Agriculture (PCA) in Uganda in 2003 which 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 equipment, especially where tree cover and/or hilly areas introduce “shadow” and projection problems.

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1 Introduction

1. 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.

2. 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.

3. 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).

4. 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.

5. The SSASP project started in 2002 and is funded by NORAD with a total of NOK 18.5 mill over three years.

6. Uganda Agricultural Censuses, considered as the backbone of the agricultural statistics system, were conducted in 1963/65 and in 1990/91. UBOS is currently planning for another Census of Agriculture and Livestock slated for 2005. As a consequence, the first 18 months of the SSASP was mainly concentrated in preparing and conducting a Pilot Census of Agriculture (PCA).

7. The basic objective with the PCA is to get experiences with tools and questionnaires, organization, economic impacts and logistics ahead of a full Census. However in addition, the extended PCA 2003 gave experience with, and possibilities for comparison between different tools and methods used for area calculation, yield measurement and thus calculation of crop production. Of which especially the latter is regarded as a very difficult and costly task in many developing countries.

8. As a result of experimental design of the PCA, a simple handheld tool for Global Positioning Systems (GPS) is tested and introduced as a cost-efficient tool for area measurement and for geo-referencing of holdings. Thereby UBOS has also embarked on the building of capacity for more extensive use of Geographical Information Systems and Technology (GIS/GIT) in the context of agricultural statistics in Uganda for the years to come.

2 Areas in the context of agricultural statistics

1. 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.

2. 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.

3. 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.

4. 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.

5. 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

6. 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.

7. Geo referencing of agricultural holdings in the context of agricultural statistics become relevant as 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 Equipment in Masaka District, June/July 2002

1. 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.

2. Experience from area measurement during the 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 however 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 and measuring tapes are considerable.

3. On this background it was decided to look for alternative methods for area measurements already as the pre test for the Uganda Census of Agriculture and Livestock was conducted in Masaka district June/July 2002.

4. 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.

5. 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.

6. 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 a signal takes from satellites in the sky to the GPS tool on the earth surface. A 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.

7. 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.

8. The registration of holding 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

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

2. 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 about upgrading for area calculation software can be found on the Garmin home pages (www.garmin.com).

3. In cooperation with experts from the National Biomass Study Project and geographers within UBOS, the instruments setup were optimized for such 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. The following setup specifications were agreed to be used:

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

4. During this preparatory experimentation the possibility for downloading vector data for each parcel and plot perimeter was discussed and tested (necessary PC software can be downloaded). 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 also regarded as being outside the scope of a census of agriculture.

5. 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 (m^2) 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	

6. 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

1. The land area measured per holding selected for the PCA was limited to that one within the selected EA and included:

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

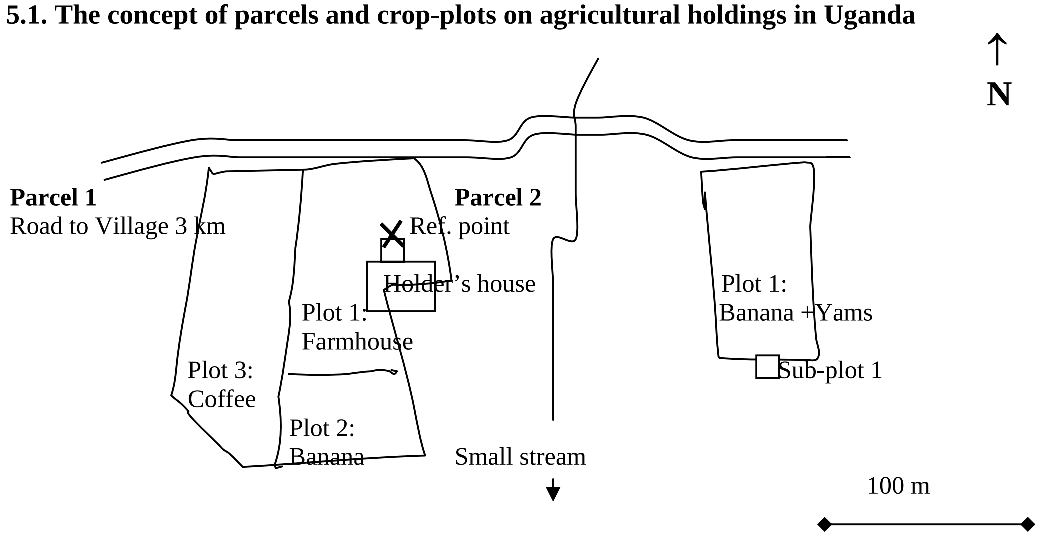
2. The experimental design of the PCA provided for four approaches to area estimation for three groups of holdings within each Enumeration Area (EA). Each EA had a total of 15 holdings selected, so each of the three randomly selected groups had 5 holdings. The experimental design for area measurements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

(i) Holders'/respondents' eye estimates of parcel and crop plot area was recorded on the 5 selected holdings in Group I.

(ii) Enumerators' eye estimates of parcel and plot area was recorded on the 10 selected holdings in Groups II and III.
(iii) Measuring using compass and measuring tapes was recorded on the 5 selected holdings in Group I.
(iv) Measuring by use of GPS equipment was recorded for all the 15 holdings in the EA i.e for all the Groups I-III.

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

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



4.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 was 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 and Enumerators' 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

1. 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 recorded the values in square meters directly on the forms and this caused some confusion in the data cleaning/data entry process.

2. Using a hand held GPS-tool is basically not much different from operating a cellular phone and thus possible 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.

3. During the fieldwork it turned out to be necessary to repeat and further drill the routines for using the GPS equipment. 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.

4. Since the GPS tool 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.

5. 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.

6. 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 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 Equipment and traversing during the PCA

1. 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 kinds of topographic and vegetation cover.

2. Initially problems with the level of 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 reveals 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

1. 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 parcels were estimated by the enumerator.

2. There were 430 observations where areas of parcels were measured by both the GPS equipment and by traversing (tape & compass). A paired T-test (see figure 5.2 and table 5.1-3) of this set of observations reveals that there is no statistically significant difference between the results of the two methods concerning parcels measured during the PCA filedwork 2003.

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

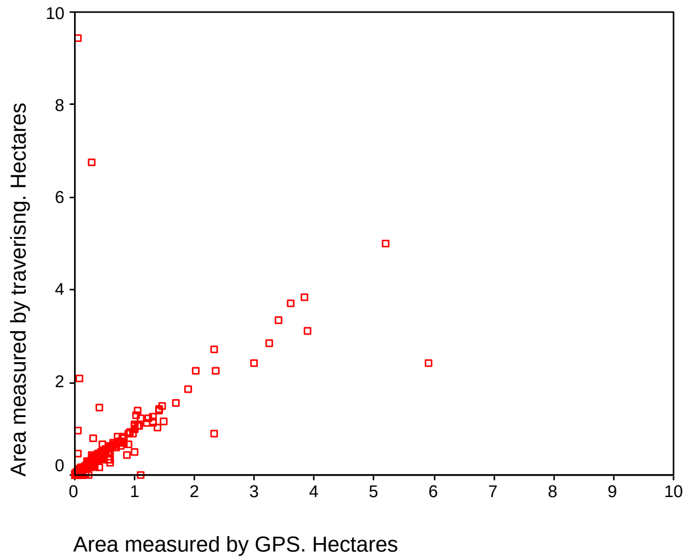


Table 5.1. Paired Samples Statistics of parcel areas

		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

3. Finally, a one-way ANOVA test was carried out to compare parcel areas measured by GPS tool, or by traversing and holders estimates. A total of 390 parcels were measured by all of these three methods. During data collection, all measurements below 100 square metres (0.01Ha) were rounded to 0.01Ha. So during the ANOVA, only areas larger than 0.01 hectare were included in the test. This avoids bias due to rounding of values for the smallest areas.

4. The results of this test is documented in table 5.4-6 below. Table 5.4 indicates that the Holders' estimates tended to be the highest, followed by the area measurement by traversing. However, as shown in Table 5.5, the differences were not statistically significant. A comparison between traversing and the GPS tool (Table 5.6) was highly non-significant. A comparison of traversing and Holders' estimates (Table 5.6) was only statistically significant at 9% level.

Table 5.4. Descriptive Statistics of Parcel Areas

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
1 Traversing	390	0.3866	0.80066	0.04054	0.3069	0.4663	0.02	9.45
2 GPS	390	0.3486	0.59140	0.02995	0.2897	0.4075	0.02	5.20
3 Holders estimate	390	0.4955	1.19238	0.06038	0.3767	0.6142	0.01	19.02
Total	1170	0.4102	0.89816	0.02626	0.3587	0.4617	0.01	19.02

Table 5.5. One-Way ANOVA test. Comparison of Parcel Areas measured by Traversing, by GPS and holders' estimates

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.532	2	2.266	2.818	.060
Within Groups	938.490	1167	0.804		
Total	943.022	1169			

Table 5.6. Duncan Post Hoc Test of Homogenous Subsets. Parcel Areas measured by Traversing, by GPS and holder s' estimates

	N	Subset for alpha = .05	
		1	2
2 GPS	390	0.3486	
1 Traversing	390	0.3866	0.3866
3 Holders estimate	390		0.4955
Sig.		0.554	0.090

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 390.000.

5.3.2 Comparative study of measurement method for Plots

1. A one-way ANOVA test comparing plot areas measured by GPS tool, measured by traversing and holders' estimates was also conducted. Again, only plot areas larger than 0.01 hectares are included in the test.

2. A total of 672 plots were measured/estimated as larger than 0.01 hectares with all the three methods. The results from this test are documented in Tables 5.7-9 below and are similar to those for parcels. In Table 5.7, the holders' estimate is the highest. While in Table 5.8, the differences are only statistically significant at 9% level. In Table 5.9, the GPS tool and traversing are highly non-significant but traversing and holders' estimates are significantly different at the 11% level.

Table 5.7. Descriptive Statistics of Plot Areas

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
1 Traversing	672	0.3370	1.71426	0.06613	0.2071	0.4668	0.02	28.40
2 GPS tool	672	0.2877	1.89170	0.07297	0.1444	0.4310	0.02	35.00
3 Holders estimate	672	0.4915	1.70499	0.06577	0.3624	0.6206	0.01	25.60
Total	2016	0.3721	1.77365	0.03950	0.2946	0.4495	0.01	35.00

Table 5. 8. One-Way ANOVA test. Comparison of Plot Areas measured by Traversing, by GPS tool and Holders' Estimates.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	15.196	2	7.598	2.419	0.089
Within Groups	6323.648	2013	3.141		
Total	6338.844	2015			

Table 5. 9. Duncan Post Hoc Test of Homogenous Subsets. Plot Areas measured by Traversing, by GPS tool and Holders' Estimates

AREA_FOR	N	Subset for alpha = .05	
		1	2
2 GPS Tool	672	0.2877	
1 Traversing	672	0.3370	0.3370
3 Holders' estimate	672		0.4915
Sig. Level		0.611	0.110

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 672.000.

3. The total dataset where the information about holders' and enumerators' plot area estimates as well as crop information are linked to information about plots measured with tape & compass and GPS tool comprised 3,580 plots. Of these, 3,086 plots were measured by GPS tool (GPS area >=0.00), 1,086 plots measured by traversing (tape & compass area >=0.00), whie 1,028 plots were estimated by the holder and finally 2,341 plot areas were estimated by the enumerator.

4. A total of 1,004 plots were found where area was both measured by the GPS tool and by Traversing (measured area both for GPS tool and by traversing >=0). Most of the measured plots were very small and in order to reveal possible differences between measurement of small and larger plots, 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 but more than 0.01Ha(N=934). The results of these T-tests are presented in Tables 5.11-13 and are all not statistically significantly different.

Table 5.11. 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 5.12. Paired Samples Correlations of Plot Areas

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

Table 5.13. Paired samples Test of Plota 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

5. 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 alowed 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 beeing equal to 0.01 hectares by the Enumerators.

5.4 Results of Comparison of Time use during PCA

1. Timeuse for the different measurement methods was recorded by the enumerator during the fieldwork of the PCA. For all observations recorded, the average timeuse for traversing with tape and compass was three times as long per holding as when GPS equipment was used (table 5.14).

Table 5.14. All observations of time used. Traversing, GPS tool and Enumerators' Estimates. PCA 2003

		Traversing	GPS Tool	Enumerators' estimate
			Observations	
N	Valid	302	538	448
N	Missing	476	240	330
			Minutes used	
Mean		153.9	55.6	46.1
Median		97.0	48.0	37.5

2. 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 paired T-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 tool was used (Table 5.4.2). Therefore it can be concluded that the GPS tool is a far more time-efficient method/tool than the tape and compass measured in terms of average time use per holding.

Table 5.15. Comparison between time use for traversing and use of GPS. Paired T-test Samples Statistics. 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

1. Even simple handheld GPS tools are relatively expensive tools. The GPS equipment model used in the PCA was a Garmin 12 channel receiver with an approximate price of US$150 per unit (2003 prices). During the PCA fieldwork, three enumerators shared two GPS tools. However, with good logistics, cost efficiency could be improved by letting even more enumerators share the same tools.

2. The use of batteries turned out to be high as it was agreed to change batteries when approximately two-thirds (2/3) of the energy was used. Since each GPS tool uses four (4) high quality AA batteries, the costs for power supply was considerable. The reccomended batteries cost an equivalent of US$1.25 per pair compared to the more common ones which cost about USCents25. Clearly, this cost could be reduced by giving the equipment to the staff only when they are ready to carry out the area measurements. Also 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.

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

4. Two GPS devices were lost during the project period due to unfortunate civil unrest in one of 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.

5. 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 programable calculator is

necessary to calculate areas captured by traversing. The total price is therefor not so different from the price of a GPS tool. On the otherhand, battery cost are zero for tape and compass.

6 Conclusions

1. 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 diffrence between the results of the two methods. Farmers eye-estimates of area size both for parcels and plots and seems 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 comparable 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

1. 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.

2. By introducing geo referencing (coordinates) and geocoding (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 geographical data such as thematic maps available at the The Uganda National Biomass Study including digital main road net, water courses, land cover classes etc.