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Improvement of area accuracy in general boundary areas in Kenya: Case study of Juja – Kiambu County

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Abstract

Land ownership in the vast Kenyan Trust land is through the process of Land adjudication. The Preliminary Index Diagrams (PIDs) are the official map documents that together with adjudication records constitute the adjudication register that forms the basis for determination and registration of interests and rights over land. The PIDs are produced from enlarged, marked and un-rectified aerial photographs; as a result they contain distortions to parcel area which more than often is a source of land disputes, especially in resolving the gap between area contained in the title deeds and the actual parcel area on the ground. Generally, the uncertainty in PID area is about 20% of the actual area. We propose a procedure that can be used to reduce large errors in PIDs by comparing ground surveyed and PID areas in Juja – Kiambu County. To achieve the objectives of this study, PIDs of 29 large plots in Juja were prepared from un-rectified aerial photographs. The area of each parcel was measured in the usual way, using plannimeter. Ground surveyed areas for the same parcels within the area of study were obtained from existing survey plans, normally referred to as folio references (F/Rs), and also through ground survey on parcels without F/Rs. The standard deviation (SD) of the differences between PIDs and ground survey (F/Rs) areas was ±12.17 hectares**.** The distortions increased with increase in areal size. A conversion equation was developed to reduce areal errors. Using the conversion equation on PID areas, the standard deviation (SD) of the differences reduced from ±12.17 to ±0.88 hectares, representing an improvement of 93%. The correction equation obtained can be used to obtain corrected parcel areas to facilitate accurate valuation of land parcels in the PID areas. This technique is simple because it requires only PID areas and it works well.

Key words: aerial photographs, PIDs, general boundary, ground survey, area correction equation, area accuracy

1. Introduction

Historically Kenya has been divided into three geographical blocks as far as land is concerned. These are; the scheduled areas, the coast and the trust lands. In the scheduled areas land was vested in the Government. Land in these areas has been alienated by creation of leasehold titles and in very few cases by creation of freehold (Simpson, 1976). The official channels for land ownership in Kenya include: adjudication; resettlement; allocation of public land by central government/local authority; inheritance; and/or purchase.

Land is categorized in three territorial domains: government, private and trust land. Government land comprises 10%; Private land 20% and Trust land 70% of the total land area (Mwenda, 2001). Interests in land can be broadly classified into three groups: customary rights governed by customary law, statutory/formal rights governed by statutory law and informal/non-formal rights under informal tenure arrangements. These three categories form the predominant land tenure systems in Kenya. Formal land ownership information consists of boundary definitions and cadastral maps that support registration of parcels. In Kenya two kinds of cadastral boundaries are used. These are fixed and general boundaries.

Fixed boundaries comprise mostly of boundaries in urban areas that are done utilizing high precision

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surveying methods, they are marked by accurately positioned concrete beacons at turning points. The outputs from such surveys are survey plans that are geo-referenced and often referenced to a national geodetic system. General boundaries were introduced along with the land reforms for individualization of land tenure. The aim was to speed-up the issuance of individual title to land owners and to realize as much cadastral coverage as possible in the former colonial native reserves. These general boundaries are described by physical features (hedges, rivers, cliffs, etc); the boundaries are surveyed using relaxed survey methods hence inaccurate and unreliable for precise parcel boundary delimitation.

The resulting maps for general boundary areas in Kenya are referred to as Preliminary Index Diagrams (PIDs) and Registry Index Maps (RIMs) which are not geo-referenced and generally of low accuracy. Several researchers have investigated the problem of general boundaries and cadastral system in Kenya (Wayumba, 2014; Myles et al., 2009, Mwenda, 2001; Adams 1969). The concept of general boundaries was originally introduced in Kenya in 1959 through the use of registry index map (GoK, 1966). Land ownership in the vast Kenyan Trust land (designated as adjudication areas) is through the process of Land adjudication of which the Preliminary Index Diagram is the official map document that together with adjudication record constitute the adjudication register that forms the basis for determination and registration of interests and rights over land and the subsequent issuance of land titles.

The Preliminary Index Diagrams are currently produced manually from un-rectified photo enlargements by the government cadastral mapping Agency (Survey of Kenya). The aerial photographs are acquired by low altitude flying aircraft covering the area intended for adjudication, through photogrammetric methods, the aerial photos are enlarged mostly at the scale of 1:2,500 and taken to the field for individual parcel boundary marking (demarcation).The enlarged, marked and un-rectified photographs are then returned to the office where the cartographers transfer each of the land parcel and attributes onto sheets of transparent plastic material, usually durafilm. After the inclusion of sheet marginal information the parcel area and queries are corrected and finally the PID product is realized which is used in the processing of titles.

The ever increasing population in Kenya has led to the increased demand for individual land ownership. Land subdivisions to smaller units are evidenced in Kenya now than never before. This situation necessitates the application of high precise surveying and mapping methods to accurately delineate land parcel boundaries and/or areas so as to avert the ever increasing land boundary disputes witnessed especially in the adjudication areas (rural areas) in Kenya.

This study aims at providing a solution to the said problem through the establishment of a reduction factor so that by its application it will enable a correction to the parcel area distortions experienced through aerial photography technique. This is also consistent with the new Land Registration Act 2012, Sec.15(2) that in part stipulates, “The parcel boundaries shall be geo-referenced and surveyed to such standards as to ensure compatibility with other documents required under this Act or any other Law” (Land Registration Act, 2012). The area of study is shown in Figure 1.

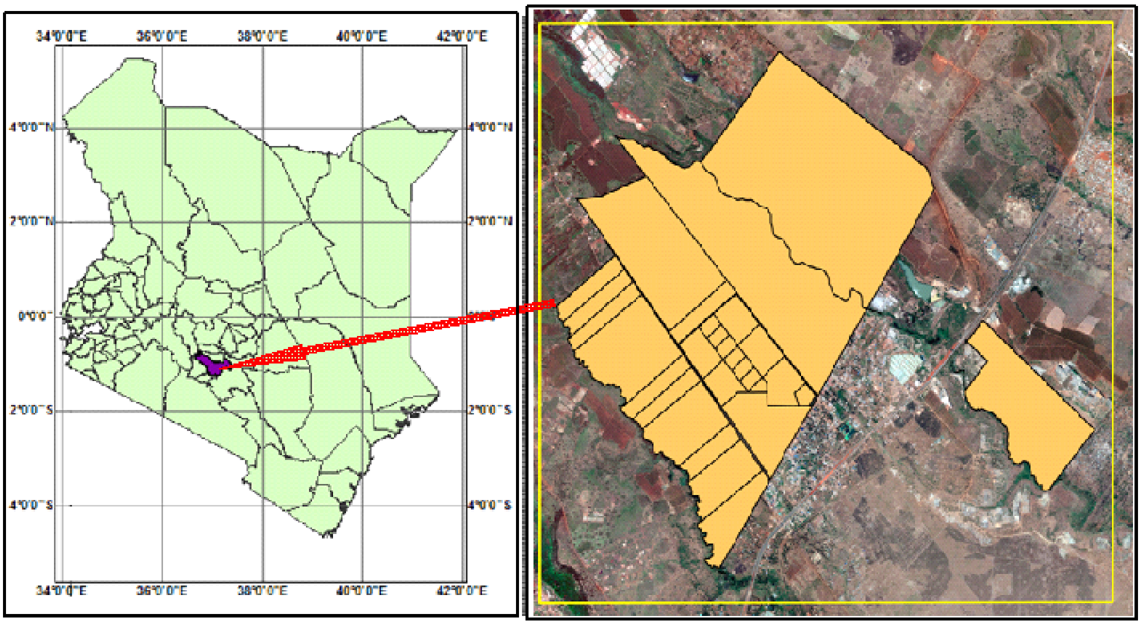

Figure 1: Area of study

2. Materials and Methods

The area of study is in Juja constituency situated about 36 km North East of Nairobi City, between Ruiru and Thika townships within Kiambu County at coordinate S 1° 02' 40" - S 1° 07' 20" and E 37° 05' 04" - E 37° 04' 50", covering about 65 km^2 (Figure 1). The area's land ownership comprises of leasehold in fixed boundaries captured in survey plans (FRs) and freehold estates in the general boundary areas mapped in registry index maps. The large farm estates which were predominantly covered by coffee plantations are currently fast diminishing paving way for subdivisions to smaller land units for residential and commercial purposes.

The data for the study include enlarged Aerial Photographs, Survey Plans, registry index map and topographical map covering the area of interest (Table 1).

Table 1 Data sets:

Data	Data description
Enlarged aerial photographs	Hard copy at the scale of 1:12,500, 1998
Registry index map (RIM)	Ruiru/Ruiru East Block 2
Topographical map	Sheet 149/1, Scale 1:50,000
Survey Plans	FR/Nos.eg. 122/117, 524/17,94/6, 78/91,85/62, 118/148, 115/70 & 71 etc.

(Source: Survey of Kenya)

2.1 Area determination from Aerial Photography Technique (PIDs)

Aerial photo covering the area of interest was obtained at the scale of 1:50,000 and enlarged to scale of 1:12,500 (Figure 2). The enlarged photo was marked using Green marker pencil, to highlight the required parcel boundaries as illustrated in Figure 3. The marked boundaries were then traced manually on to a transparent plastic material (dura-film) as shown in Figure 4. Two area measurements were performed for each parcel using the manual planimeter as demonstrated in Figure 5. The average of the measured areas of individual parcel was adopted. The results of land parcel areas from PIDs are given in Table 2.

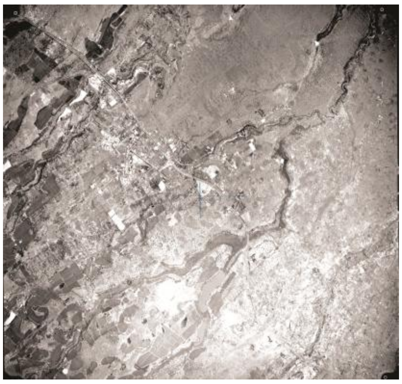

Figure 2: Aerial photo

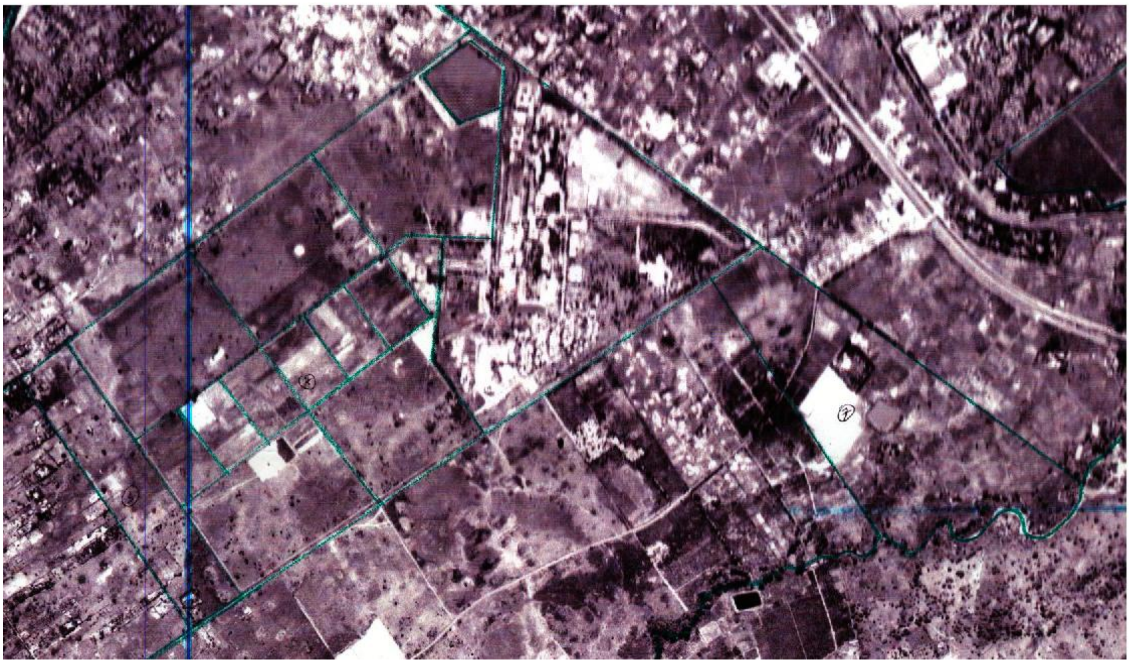

Figure 3: Marked, enlarged aerial photo

Figure 4: Manual tracing of marked boundaries onto dura-film

Figure 5: Manual area measurement using a planimeter

2.2 Area determination from Ground Surveys

Ground surveyed areas for the land parcels within the area of study were obtained from existing survey plans (F/Rs), and also through ground survey on parcels whose areas, were not determined. We used total station carry out ground survey for such land parcels. A sample of one of the survey plan used for data extraction is shown in Figure 6. Control points within the area were identified and used to run a traverse adequately controlling the whole area, then occupying the new traverse points in turn, the corner points defining the various plot boundaries were surveyed and necessary processing of data carried out including angular and linear adjustments. The final, corrected co-ordinates were used to compute areas for all the plots (Table 2).

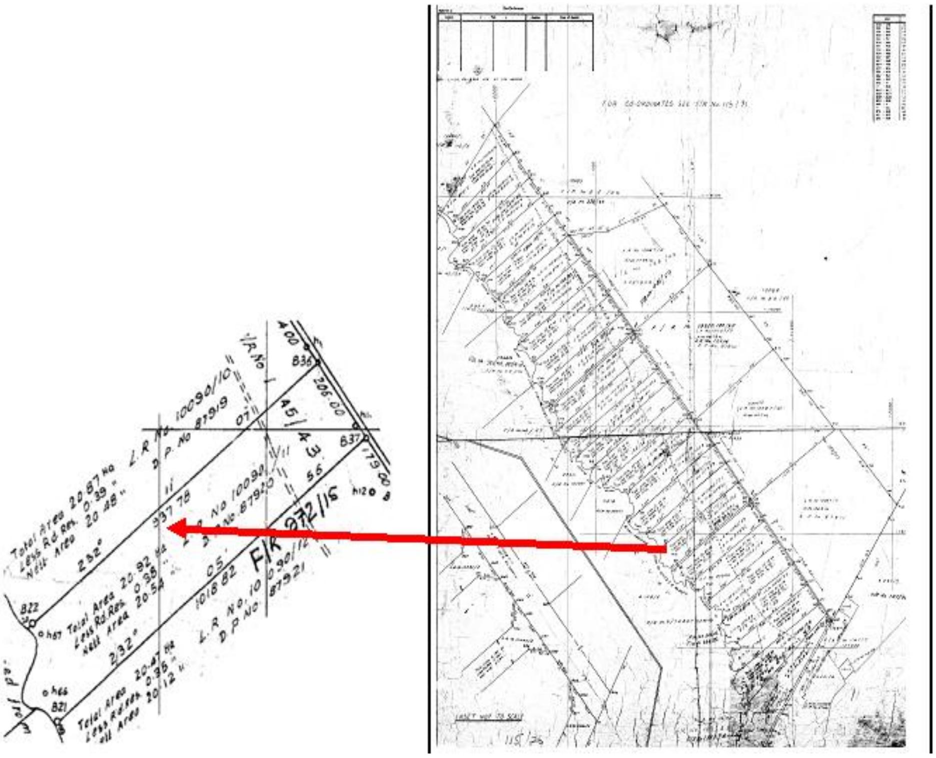

Figure 6: A sample of Survey plan of AOI

3. Results and Discussions

3.1 Comparison of Areas from Ground survey and PIDs

Among the objectives of this study was to investigate the effect of area, slope and elevation in the accuracy of PIDs and to generate the area correction factor (equation). It involved establishing the extent to which areas, elevations and slope distances obtained by aerial photography technique deviated from the equivalent ground survey. The results of compared parcel areas generated from ground surveys and aerial photography are given in Table 2. The differences between ground survey (GS) and PID areas are also shown in Figure 7. It is evident that PID areas are consistently larger than the actual (ground survey) areas in the area of study. This observation is only true within the limits of the study area, hence cannot be generalized for the whole country (Kenya). The under-representation of areas in PIDs ranges between 4.7 to 13.6% of the actual areas. The standard deviation of the differences between ground surveyed and PID areas is ±12.17 hectares. We note the cubic relationship between area size and the difference between ground surveyed and PID areas (Figure 7).

Table 2: Differences between ground surveyed and PID areas for parcels of land

Parcel No	Area (Ha)			
	Ground Survey	PID	GS - PID	% Difference
1	161.80	144.29	17.51	10.82
2	517.61	474.62	42.99	8.31
3	312.83	278.99	33.84	10.82
4	205.73	182.68	23.05	11.20
5	19.77	18.03	1.74	8.80
6	176.68	158.10	18.59	10.52
9	402.18	363.39	38.79	9.64
10	92.96	84.84	8.12	8.73
11	20.12	18.95	1.17	5.82
12	64.17	58.69	5.48	8.54
13	19.64	17.79	1.85	9.42
14	21.06	19.28	1.78	8.45
15	101.77	91.09	10.68	10.49
16	21.37	20.37	1.00	4.68
17	21.22	19.95	1.28	6.03
18	22.40	19.64	2.77	12.37
19	42.59	40.13	2.46	5.78
20	144.36	131.19	13.18	9.13
21	124.99	114.65	10.35	8.28
42	21.06	19.14	1.92	9.12
46	2.94	2.64	0.31	10.54
47	4.56	4.16	0.40	8.77
48	4.57	3.95	0.62	13.57
49	4.57	4.13	0.44	9.63
50	4.54	4.22	0.32	7.05
51	19.25	18.09	1.16	6.03
52	4.55	4.01	0.54	11.87
53	4.61	4.01	0.60	13.02
54	17.03	15.56	1.48	8.69
Mean			8.43	9.18
SD			12.17	2.22

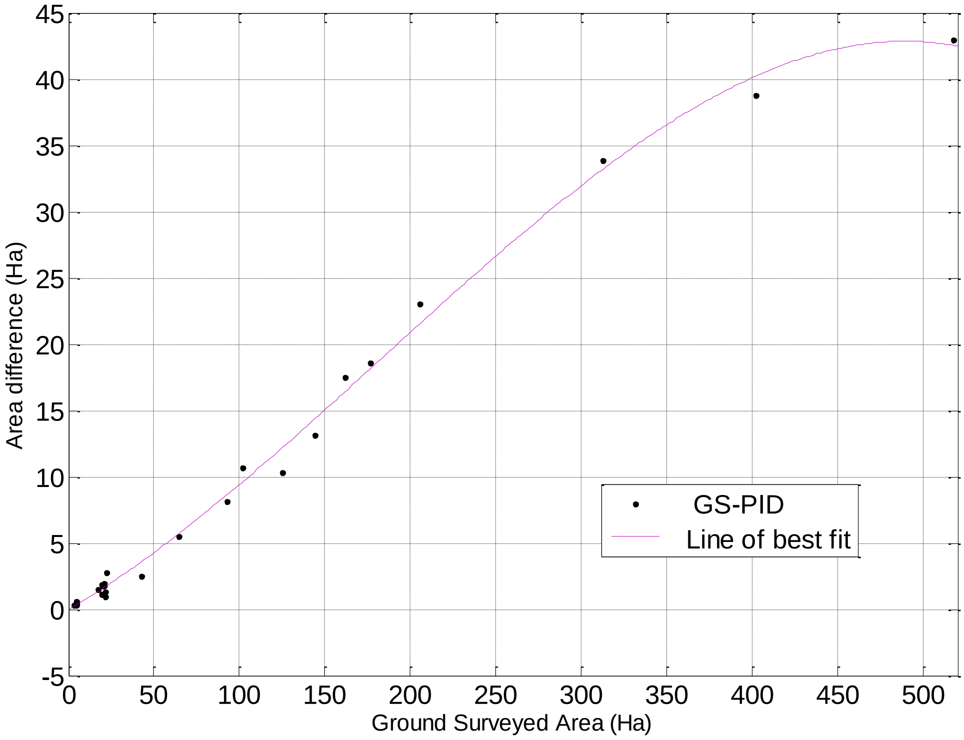

Figure 7: Differences between ground surveyed and PID areas

3.2 Correction Equation

An analysis of area deviation of Aerial photo PID from the ground surveyed areas demonstrated a general increase with increasing parcel acreage. A cubic polynomial equation was fitted on the differences between ground surveyed and aerial photo PID areas for the computation of area correction to the PID areas. The cubic polynomial for computing area correction is given in equation (1).

$$A^C = -0.00000057A^3 + 0.00028A^2 + 0.084A - 0.054 \qquad (1)$$

where, A^C is the area correction and A is the PID area in Ha.

The corrected areas, after the application of area correction equation (1) on aerial photo PID areas are shown in Table 3. The differences between ground surveyed and improved PID (IPID) areas are presented in Figure 8. The differences between ground surveyed and PID areas are also shown in the same figure for visual comparisons. It can be seen that the correction equation reduces the area deviation between ground surveyed and aerial photo PID from SD of ±12.17 to ±0.88 Ha. The improved PID (IPID) area is computed as given in equation (2). The last column of Table 3 represents the difference between improved PID (IPID) and ground surveyed (GS) areas.

$$IPID = PID_{area} + A^C \qquad (2)$$

Table 3: Application of correction equation

Parcel No	Area (Ha)				
	Ground Survey (GS)	PID	Correction (A^C)	Improved PID (IPID)	GS- IPID

1	161.80	144.29	16.18	160.47	1.33
2	517.61	474.62	41.95	516.57	1.04
3	312.83	278.99	32.80	311.79	1.04
4	205.73	182.68	21.16	203.84	1.89
5	19.77	18.03	1.55	19.58	0.19
6	176.68	158.10	17.97	176.07	0.61
9	402.18	363.39	40.09	403.48	-1.30
10	92.96	84.84	8.74	93.58	-0.62
11	20.12	18.95	1.63	20.58	-0.46
12	64.17	58.69	5.73	64.42	-0.25
13	19.64	17.79	1.53	19.32	0.32
14	21.06	19.28	1.67	20.95	0.11
15	101.77	91.09	9.49	100.58	1.19
16	21.37	20.37	1.77	22.14	-0.77
17	21.22	19.95	1.73	21.68	-0.46
18	22.40	19.64	1.70	21.34	1.06
19	42.59	40.13	3.73	43.86	-1.27
20	144.36	131.19	14.50	145.69	-1.33
21	124.99	114.65	12.40	127.05	-2.06
42	21.06	19.14	1.65	20.79	0.27
46	2.94	2.64	0.17	2.81	0.13
47	4.56	4.16	0.30	4.46	0.10
48	4.57	3.95	0.28	4.23	0.34
49	4.57	4.13	0.30	4.43	0.14
50	4.54	4.22	0.31	4.53	0.01
51	19.25	18.09	1.55	19.64	-0.39
52	4.55	4.01	0.29	4.30	0.25
53	4.61	4.01	0.29	4.30	0.31
54	17.03	15.56	1.32	16.88	0.15
Mean					0.05
SD					0.88

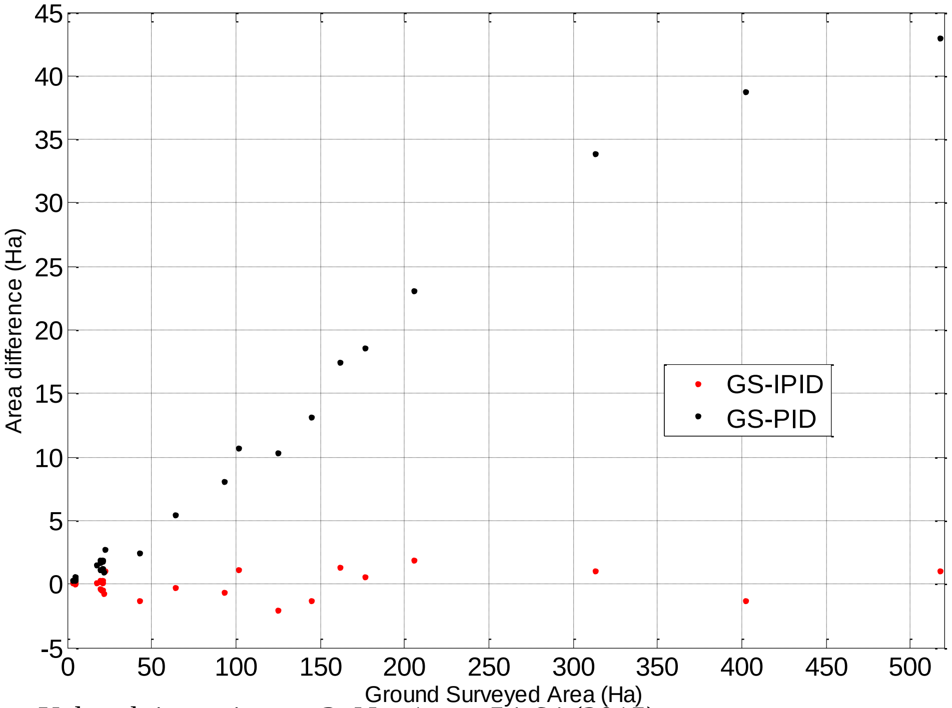

Figure 8: Differences between ground surveyed and IPID areas compared with the differences between ground surveyed and PID areas

3.3 The effect of elevation on the accuracy of the PID areas

The elevations were extracted directly from contours corresponding to each parcel, whereby a difference between the highest and lowest contours was computed and recorded thus providing elevation (vertical distance) for the respective parcels. This was followed by computation of area averages that fall within same elevation. The correlation between area accuracy with varying elevation is as shown in Figure 9.

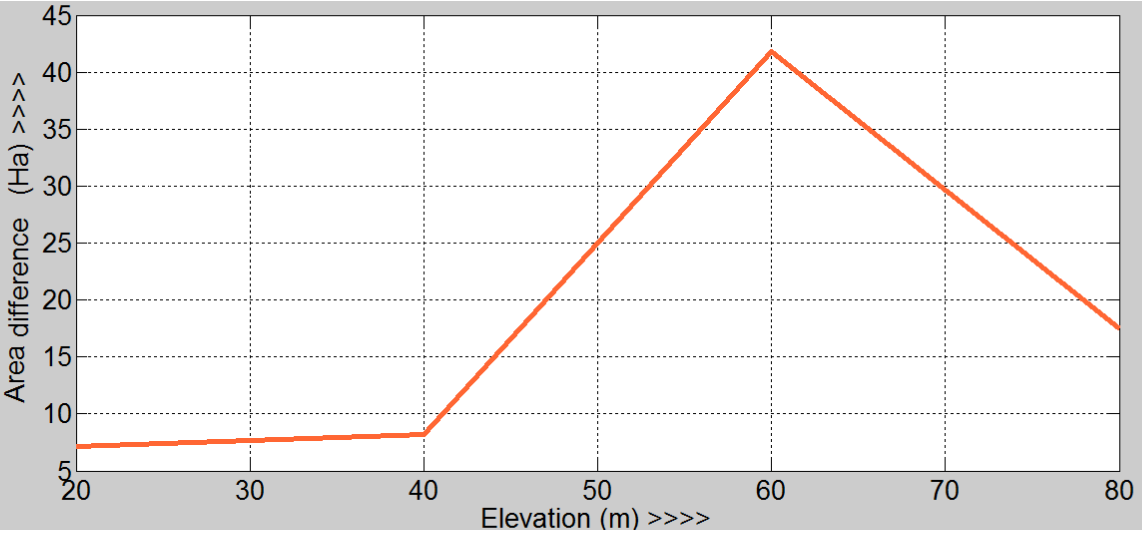

Figure 9: Effect of elevation on area accuracy

From the results, safe for the few points available for analysis, generally the increase in elevation also increases the deviation of Aerial PID areas from the actual ground surveyed areas, that is, at higher elevations the distortions to aerial PID areas is larger than in relatively lower areas. This effect is recommended for further studies. The elevation variation in the area of study was not sufficient to establish a reasonable trend.

3.4 The effect of slope on the accuracy of PID areas

The slope distances for each parcel were obtained by adopting an average of two parallel boundary lines defining a parcel and by applying the general formula,

$$SLD = \sqrt{V^2 + H^2}, \qquad (3)$$

where, SLD is the slope distance, V is the vertical difference and H is the horizontal distance.

A graph showing the correlation between area accuracy with varying slope distances is shown in Figure 10. From the results, it is evident that the effect of increase in slope distance is directly proportional to the increase in area distortion of aerial photo PID with respect to equivalent actual ground surveyed areas. Again this effect is recommended for further studies using various slope distances to establish a specific relationship. Our area of study is limited in topographical variations necessary for slope analysis.

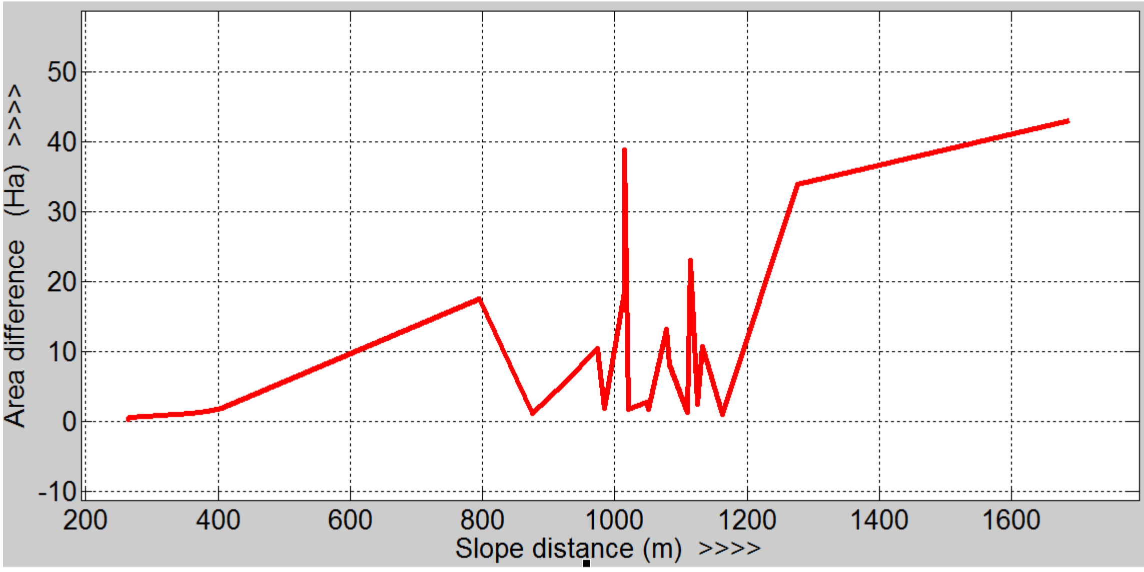

Figure 9: Effect of slope distances on area accuracy

4. Conclusions

From the results obtained, it is clear that distortions on parcel areas are directly proportional to the parcel size (acreage), that is, the PID area deviation from the actual (ground surveyed) area increases with increasing area size. It is also determined that deviation of PID parcel area from the actual area generally increases with increase in slope and elevation, although our data was not sufficient to facilitate a scientific verification on the effects of slope and elevation on the area accuracy.

We have demonstrated that the PID areas can be improved without necessarily conducting new ground surveys by applying a correction function to PID areas. Using the conversion equation on PID areas, the standard deviation of the differences between ground surveyed and PID areas reduces from ±12.17 to ±0.88 hectares, representing an improvement of 93%. The mean of the differences between ground surveyed and PID areas also reduces from 8.43 to 0.05 hectares, representing an improvement of 99%. The correction equation obtained can be used to obtain corrected parcel areas to facilitate accurate valuation of land parcels in the PID areas. This technique is simple because it requires only PID areas and it works well. We recommend a comprehensive study covering a larger area to reveal any trends in the effects of slope and elevation on the area accuracy. Such trend(s) can be used to improve the current correction equation determined in this study.

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References

Adams, L.P. (1969). *The Computation of Aerial Triangulation for the Control of Cadastral Mapping in High Density Agricultural Areas*. PhD. Thesis. University of Nairobi.

Government of Kenya. (1966). Report on the Mission on Land Consolidation and Registration in Kenya. *The Lawrance Mission Report.*

Land Registration Act. (2012). National Council for Law Reporting, No.3, pp. 164.

Mwenda, J.N. (2001). Spatial Information in Land Tenure Reform with Special Reference to Kenya. *Proc. Int. Conference on Spatial Information for Sustainable Development*, Nairobi, Kenya, 2nd – 5th October, 2001.

Myles, A., & Bwire-Lund, K. (2009). Improving Land Administration in Kenya. *Ministry of Lands, Version Publication*.

Simpson, S.R. (1976), *Land Law and Registration.* Cambridge University Press.

Wayumba, G.O. (2013). *An evaluation of the cadastral system in Kenya and a strategy for its modernization.* PhD. Thesis. University of Nairobi.