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Accuracy Assessment Of Preliminary Index Diagrams (PIDS) From High Resolution Orthoimages In Kenya

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Abstract: In Kenya, various types of cadastral maps are in use for land administration; the most famous being Registry Index Maps (RIMs) used in the rural areas due to their ease of production by simple surveying techniques and air survey methods. Such RIMs initially intended as a temporary measure to speed up land registration pending preparation of more accurate documents, are still in use today resulting in unreliable and lack of up to-date survey information for better land administration. This study investigates a new system that would facilitate quick production of reliable, accurate and up to-date cadastral maps for land administration through the use of high spatial resolution satellite imagery (QuickBird). Three types of data were acquired and integrated to provide a database; namely QuickBird orthoimage, orthophoto and parcel areas from the RIMs. The evaluation was made by statistically comparing parcel areas from, orthophoto (reference data), QuickBird satellite orthoimage and the official PID Area List.

The study has demonstrated that the high spatial resolution satellite imagery can be used as an input for indirect land surveying methodology. Statistical analysis indicated that there was no significant difference between parcel areas from orthophoto and satellite orthoimage while there was significant difference between PID and orthophoto areas. Good results were obtained for large and medium size parcels with an average area difference of 0.3% and 1.0% respectively and 2.6% for smaller sized parcels. However, with regard to the minimum requirements for a Land Registry Index Map to be of sufficient accuracy to perform its core functions of parcel identification, boundary relocation, mutation surveys and area computation, it can be reasonably concluded that PIDs from QuickBird orthoimage at a scale of 1:5000 met these requirements.

Keywords: Land registration, Land titling, cadastral maps, PIDs, QuickBird, orthoimages, accuracy.

I. INTRODUCTION

Maps are used for land registration, but the registration is incomplete if the object cannot be unambiguously identified on the ground. An efficient land registration system is one that has a proper cadastral basis and is reliably georeferenced. It has been universally accepted that the best registration system is the registration of titles. Each parcel is described on a map with well-defined boundaries, accurate cadastral index maps and is given a special entry in a register showing all existing rights in the parcel (Ariyaratne, 2003; Mwenda, 2001).

One major setback in the title registration under Registered Land Act (RLA) in Kenya is the lack of accurate and reliable large-scale maps. In an attempt to produce large-scale maps for title registration, using PID, the accuracy was compromised. To resolve the above challenges, Mwenda (2001) recommended the use of high spatial resolution satellite imagery such as IKONOS and QuickBird. Such imageries are useful sources of information for land management, especially in land adjudication. At the moment, however there has been no study to assess the suitability of high spatial resolution satellite imagery in Land Adjudication in Kenya.

Consequently, this study seeks to look at the possibility of using the combination of the modern technologies of remote sensing, digital mapping, and GPS, in the development of a more accurate approach to the establishment of boundaries and geo-referencing of parcels in the registration of land parcels under RLA. The objective of this study can thus be stated as: to evaluate the suitability of high spatial resolution satellite imagery for use in the production of PIDs for adjudication survey in Kenya.

II. BACKGROUND

The importance of land in an agricultural economy needs no emphasis. It constitutes the primary form of wealth and source of political power (Konyimbih, 2001). Kenya is an agricultural economy hence land is its economic mainstay. It has therefore been a government policy to: (i) improve the quality of life through increased agricultural productivity in rural areas, (ii) to transfer land ownership through an orderly land transfer programme and (iii) to create security of tenure through an accelerated programme of land consolidation, adjudication and registration (UN-HABITAT, 2001).

A. THE LAND ADJUDICATION PROCESS IN KENYA

The registration of rural lands in Kenya in accordance with RLA was conceptualized as a large scale project to have the lands under African ownership in rural Kenya registered. Ground based survey methods could not be used because the technical procedures of land consolidation were expensive and too slow to sustain the high demand of titles. The survey techniques adopted were to be kept simple, requiring only the use of the simplest pieces of equipment such as the surveyor‟s chain. Under this mass land adjudication, the boundaries of parcels were walked and determined by the elders or committee members and the demarcation officer planted the hedges. Once the boundaries were established, the boundary owners marked them with hedges. In order to produce the maps of the parcel boundaries, air photography of the entire adjudication area was carried out. This would show the parcel boundaries as marked by hedges, and through the direct tracings of such boundaries from the photographs the respective plot boundaries could be shown in map form. It was originally intended that once the boundaries were air visible, new aerial photographs would be acquired at a scale of 1:12500 to generate more accurate maps. This process for the new acquisition was known as the "re-fly", as proposed by Adams (1969). The process was however later abandoned due to lack of funds and administrative bureaucracy.

From the above discussion, the photographs were simply used without any corrections for errors being applied on them. The photographs were thus simply enlarged five times to a scale of 1:2500 to facilitate the production of representative diagrams of the parcels on transparent paper. The resultant intermediate maps were viewed simply as preliminary diagrams and were consequently referred to as Preliminary Index Diagrams (PID). They were referred to as diagrams because the photographs used to produce them were unrectified. The second phase of the program to produce Registry Index Maps (RIM) has not been executed in most parts of the country thus the PIDs have in fact remained as the official map for registration under RLA. The intended production of parcel boundaries from the rectified photographs after the "re-fly" was to result in Registry Index Maps (RIM). This however was never executed as has been explained and PIDs have remained the official „map‟ for registration under RLA. The use of PIDs for registration in Kenya has served the country well for over 50 years. However due to rapid technological and global changes, it is evident that PIDs can no longer cope with the demands of a modern economy. If the country has to attain its vision of industrialization by the year 2030, there will be a need to modernize the land adjudication system in Kenya in order to provide a reliable spatial data framework upon which the industrialization concept can be anchored.

B. THE CHALLENGES OF LAND ADJUDICATION PROCESS IN KENYA

Kenya has a land registration the system that lags behind technologically. The survey standards were compromised in the production of registration maps thus reducing their importance and efficacy as instruments of land registration. As has been indicated, the majority of title registration in Kenya within the rural areas is based on the PIDs. The following challenges have been noted.

- ✓ The process of registration has moved on quite slowly to the extent that although it has been in operation for close to fifty years, hardly 30% of the country has been covered (Aduol, 2006).
- ✓ The accuracy in acreage of land registered under RLA is guaranteed only to within an error of 20% or more. Discrepancies exceeding 50% in parcel areas have been obtained from some of the PID when compared with those obtained from more accurate survey methods (Mulaku, 1995).
- ✓ Land proprietors never realize the full potential of their parcels in terms of monetary support from the financial institutions for development. For instance, land registered under RLA and based on PID is advanced only 40% of the property as compared to 90% in the case of titles registered RTA (Mulaku et. al., 1996). This has the potential to lessen the tenure security of primary right holders in a manner that would endanger the trust needed for transactions and mortgaging, which are a prerequisite for desirable long-term investment.
- ✓ The government does not guarantee the land parcel area as shown on the register but only the parcel‟s existence on the register (Njuki, 2001). This has given rise to boundary disputes that often take longer periods to arbitrate thereby leaving land parcels idle thus uneconomical for long periods.
- ✓ The PIDs have non-uniformity of the scale within particular registry map sheet, unreliable areas and distortion of shapes of parcels since there are no standard specifications for boundary features for general boundaries. Continuous features, such as hedges and fences often mark boundaries, but quite often these features are missing. Though the approximate scale is indicated on PID map sheets, indication of grid lines on the sheets is avoided.
- ✓ There are also problems associated with the use of these maps for registration, as they never offer secure and valuable land tenure (Ogalo and Wayumba, 2002). Accurate demarcation of boundaries will minimize litigation emanating from indeterminate boundaries, ensure certainty in land ownership, land tenure, land right and facilitate the registration of right in customary land

and subsidiary interests and promote valuable development information which will enhance sustainable national development.

In spite of the many observed weaknesses in the system, Kenya still has one of the best land registration systems in the developing world; that is relatively cheap and effective.

III. DESCRIPTION OF THE STUDY AREA AND DATA

A. STUDY AREA

The study area is located in Machakos district, Kiandani Registration Section (figure 1). Located in the Eastern region of the country, this area includes a number of plains and low rugged mountain ranges. Generally the study area was chosen for its diverse set of terrain features, data availability and proximity to Nairobi. The aerial photographs were available at a scale of 1:12 500 and 1:20 000; the satellite imagery was of good quality with a cloud cover of 3%; PIDs of continuous coverage and their Area List were available. However, the aerial photography was not controlled hence there was need to provide controls.

B. DATABASE

Three types of data were integrated to provide the database used in this study; namely QuickBird orthoimage, aerial photographs and PIDs. The software available for use in the study include: ERDAS IMAGINE (Version 8.6 and 9.0), ArcView 3.2, Leica Geo-Office, Spectrum software, Ashtech Solutions 2.70, AutoCAD 2005, Statistical Package for the Social Sciences (SPSS) and Excel. The equipments included Contex Wide Format Scanner, Sokkia and Leica GPS receivers and a hand held GPS receiver.

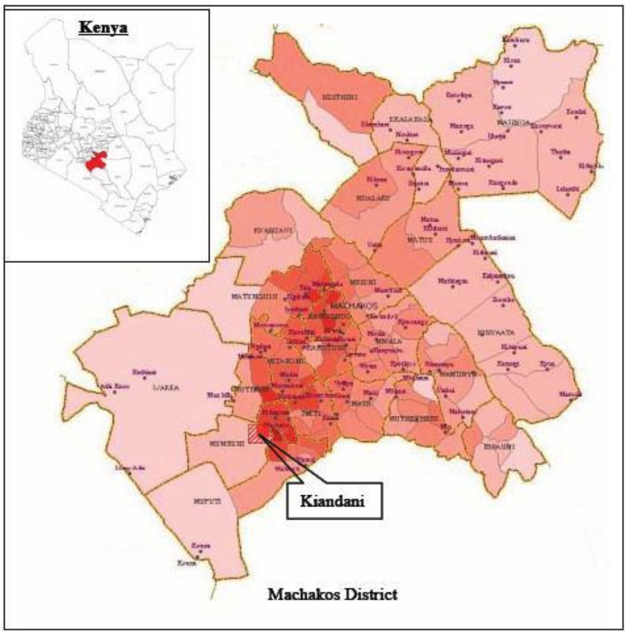

Figure 1: The study area, Kiandani Registration Section

IV. METHODOLOGY AND RESULTS

This study proposed a conceptual model (Figure 2) to evaluate and analyze field data to determine the suitability of high spatial resolution satellite imagery for use in cadastral mapping. The overall research approach was mainly focused on the comparison of different datasets from which the parcel areas were extracted and evaluated by means of statistical analysis. The main assumption of the study was that the parcel areas obtained from satellite orthoimage and orthophoto are equal and that there is a difference in the case of PIDs versus orthoimage. These assumptions formed the basis for the hypothesis and the subsequent tests. The study sought for the prospects of integrating geospatial technologies in cadastral studies.

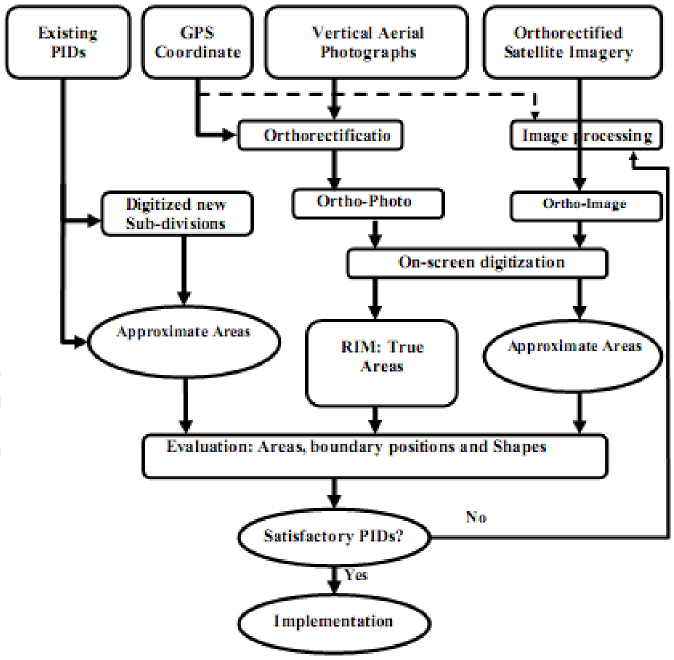

Figure 2: The conceptual framework

The use of aerial photography played a major role in cadastral mapping and presently high-resolution satellite data is providing the needed accuracy for cadastral level mapping at 1:4000 or better scale. QuickBird is currently the satellite imagery with the highest resolution for civilian uses (at 60cm) and thus was the choice for this study. The study uses parcel area information from orthophoto, which is assumed to represent the true ground area as the reference data and forms the basis for comparison. To obtain the orthophoto, this research utilized archive photographs (scale of 1:12500) which were scanned, georeferenced using GPS coordinates, oriented (interior and exterior), and processed for digital elevation model extraction and orthorectification. The GPS receivers were used in differential mode of surveying. This mode is recommended for photo scales in the range of 1/4000-1/50000 (Chandler, 1999). Parcel area information from orthophoto and orthoimage were obtained through on-screen digitization of parcel boundaries

While the orthophoto was produced for the study, the orthoimage was ready made from the supplier. The main reason for this was to cut down on the cost of production of

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PID from the orthoimage by bypassing the processes of orthorectification using GPS coordinates and image processing. Parcel area information was obtained in a similar manner as from orthophoto. In the case of PID parcel areas, the information was contained in the PID Area List provided by Survey of Kenya. Parcel classification with respect to acreage was conducted according to Labor Force Survey Report of Kenya (1998/9). According to this report, parcels have been classified into:

- ✓ Class A : (0.01 – 0.99 ha)
- ✓ Class B : (1.00 – 2.99 ha)
- ✓ Class C : (3.00 – 4.99 ha)
- ✓ Class D : (≥5.00 ha)

The evaluation was made by comparing the resulted digitized data from orthophoto image measurements – reference data – and the one from the orthoimage identification – extracted data and PID areas for each parcel encountered in the study area. Cadastral surveying analysis are mainly composed of comparisons of areas and distance between vertices among the distinct data as shown in tables and figures below.

KIANDANI REGISTRATION SECTION				
Parcel areas in hectares				
		[a]	[b]	[c]
No.	Plot No.	Satellite	Orthophoto	PID
1	2474	0.10	0.11	0.21
2	65	0.14	0.14	0.22
3	3870	0.19	0.18	0.22
4	225	0.21	0.22	0.20
5	2355	0.24	0.24	0.16
6	2401	0.30	0.31	0.30
7	2402	0.30	0.31	0.32
8	3869	0.32	0.33	0.30
9	3459	0.34	0.34	0.30
10	56	0.35	0.34	0.39
11	3846	0.35	0.35	0.35
12	64	0.35	0.36	0.30
13	172	0.44	0.44	0.47
14	2028	0.47	0.47	0.80
15	42	0.49	0.47	0.60
16	9	0.47	0.48	0.38
17	53	0.44	0.49	0.60
18	3001	0.49	0.50	0.51
19	3002	0.49	0.51	0.46
20	154	0.50	0.53	0.70

Table 1: Sample parcel areas from orthoimage, Orthophoto and PID

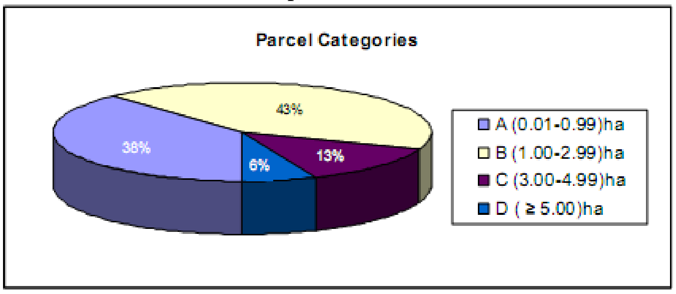

Figure 3: Distribution of parcels in the study area with respect to size

Figure 5: Delimitation of parcels on the orthoimage

Figure 6: Delimitation of parcels on the orthophoto

Figure 7: Difference in vertices between overlaid parcel on orthophoto (blue) & orthoimage (pink)

Parcel Sizes				
Category	Freq.	% Var1.	% Var2.	% Var 3.
A (0.01-0.99) ha	48	16.2	16.6	2.6
B (1.00-2.99) ha	54	8.7	8.8	1.0
C (3.00-4.99) ha	16	6.6	6.6	0.3
D (≥5.00) ha	8	3.4	3.3	0.3

Var1 = Average parcel area difference between orthophoto & PID
Var2 = Average parcel area difference between Satellite & PID
Var3 = Average parcel area difference between orthophoto & Satellite

Table 2: Parcel categories

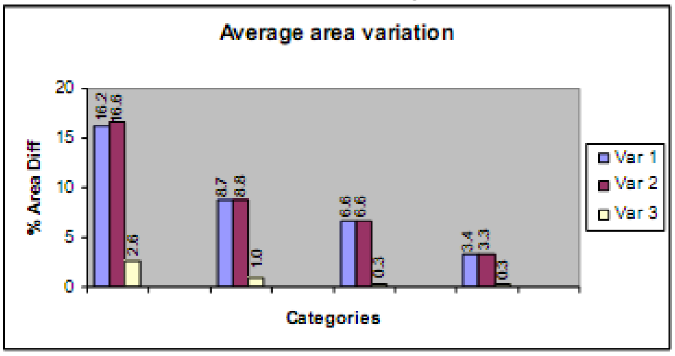

Figure 8: Area variation per category

Range (%)	Frequency	Percent
≤10	125	99.2
11-20	1	0.8
Total	**126**	**100**

Table 3: Percentage area difference between orthophoto and orthoimage

Range	Frequency	Percent
≤10	83	65.9
11-20	28	22.2
21-30	11	8.7
31-40	1	0.8
41-50	3	2.4
Total	**126**	**100**

Table 4: Percentage area difference between orthophoto and PIDs

The study was carried out on rural properties bordering an urban centre. The land parcels considered in the study were easily identified on both the orthophoto and the satellite orthoimage. The parcel boundaries were characterized by trees, live enclosure or fences with presence of vegetation, roads or foot paths and water drainage with the presence of low altitude vegetation. Statistical analyses carried out on the parcels indicated that there was no significant difference between the orthorectified aerial photographs (orthophoto) and satellite image (orthoimage) for computing areas for land registration. On the other hand, there was significant difference between PID and orthophoto areas. The paired sample tests indicated that PID areas tend to be bigger as compared to the orthophoto areas while the opposite is true in the case of orthoimage. Bigger PID parcel areas were attributed to the variation of scale due to tilt. As the angle of tilt increases, the scale of photography becomes smaller. When scale gets smaller, the error quantity increases, consequently the bigger the distortion of parcel size and shape.

Majority of the parcels from the orthoimage had their area differences below 10%. A similar trend was repeated with the PID areas. In comparison to orthoimage areas, the PID areas had fewer parcels in the same range as shown in table 3 and 4. Some of the PID parcel areas were found to be in error of up to 50%. Mulaku, (1995) indicated that an error up to ±2% in area and ±2m in position was acceptable to the majority of map users in Kenya. With this level of accuracy, 81% of parcel areas from the satellite orthoimage were found to be within this range. Further analysis indicated that the smaller the parcel, the greater the error on their areas and vice versa. Figure 8 shows a summary of average area variation and the general trend taken by this variation on the parcel categories. It was also observed that land parcels with an elongated shape had larger errors in their areas as compared to the rest. Perhaps this is a good indicator as to the shape of parcels that should be adopted during land sub-division and adjudication exercise. Figure 9 depicts this scenario.

Figure 9: Parcels (in red) with biggest errors

A. RURAL PROPERTIES

For large extension in gentle terrain, boundaries were easily identified in both the orthoimage and orthophoto. In this case, field borders are trees, live enclosure or fences with presence of vegetation, roads or foot paths and water drainage with the presence of low altitude vegetation. Variation between the reference data and the extracted one from orthoimage is very low (<3%) as observed in table 2. There is a significant difference of result depending on the size of the property. Properties in category „B", „C" and „D" presented an average area variation of 8.6%, 6.6% and 3.3% for PIDs respectively. However, the difference between parcel sizes is small (1.0%) and tends to zero as the parcels become bigger in the case of orthoimages.

B. URBAN PROPERTIES

Category „A" mainly consist peri-urban parcels, with a combination of residences and survival cultures. Average area variation was 2.6% (orthophoto and orthoimage) and above 16% (orthophoto and PID). Most of the cases presented no physical boundaries, only „legal invisible" fences. The borders were barely identifiable in the orthoimage and orthophoto, making the delimitation of boundaries almost impossible. This is mainly due similar spectral response of the building and its surrounding, where no contrast is identified the accuracy of image identification drops.

V. ANALYSIS AND DISCUSSION

The logic behind the use of high-spatial resolution imagery over aerial photographs is that, land titling can now be achieved much more rapidly than in the past by combining indigenous local knowledge of traditional boundaries with use of modern geospatial technologies. The introduction of high-resolution satellite imagery presents another opportunity for quick, cheap and accurate mapping and hence a quick solution to current land conflicts in Kenya today. The operational method for this study can be suggested for the integration of remote sensing data and field data for the production of accurate registry index maps. Feature extraction from satellite imagery can be done through on-screen digitization with input of spatial information from field data. Thus the output can estimate the parcel areas more accurately in the form of a continuous parcel map with geographical extent, which will best compare with the actual parcel areas on the ground. This map can as well be referred to as registry index map due to their levels of accuracy. Apart from the parcel boundaries, the satellite imagery would show extra details such as the vegetation type, houses, road types, infrastructural services etc. These features would improve the quality of existing cadastral maps thus making them more suitable for land transaction, infrastructural mapping, land valuation and taxation purposes. The image used in this study presented some limitations, the presence of clouds and haze restricts the area of utility and the identification of parcel borders is more complex. However, in this study more accurate results were obtained for medium size parcels (category B, C, D) than for small ones (category A). This is because the borders for category „A" parcels were barely identifiable in the orthoimage and orthophoto, making the delimitation of boundaries almost impossible.

As can be observed, the variation of the parcel area between the orthophoto (reference data) and the one derived form the image interpretation (orthoimage) depends directly on the size. The variation of area was considered very low for larger parcels. However, smaller parcels in small agricultural areas and peri-urban properties presented a considerable variation of the area. This large variation of the areas can have significant consequences in land development planning and legal aspects. The use of quickbird orthoimages as a tool for the indirect method for cadastral projects seemed interesting for properties of medium and large acreage. Nevertheless, small rural properties, peri-urban and urban estates were not well identified presenting an important variation of their area. Land tenure mapping requirement in Kenya are of two (2) kinds: Base mapping and Registry Index Mapping (RIM). The base mapping is done at a scale of 1:2500 with contours at 10 feet vertical interval. The accuracy requirements for ground controls for these maps should be as good as ±4 feet for height while the planimetric positions are plotted to within plotable accuracy. The RIMs are provided on standard sheet-lines at 1:50000, 1:10000, 1:5000 and 1:2500 depending on the size of the farm. Their accuracy is such that they conform to the accepted international standards i.e. that 90% of all well defined points shall be plotted to within 0.5mm of their true position at map scale. Results and observations of the study show that high spatial resolution satellite imagery like QuickBird has a potential as a source of data within a national mapping agency. It has been demonstrated that imagery of this type can be used for several different purposes, and it is this multiple use which makes the imagery a viable tool in this context. Recent works show that the geometry of QuickBird or Ikonos imagery are accurate enough for mapping purposes up to scale of 1:5000 (Büyüksalih and Jacobsen, 2005; Alexandrov et. al., 2004). Further research has shown that QuickBird satellite image can be used for mapping up to a scale of 1:2000 with enough GPS control points (Trần, 2005) accurately plotted with a root mean square in the range of 0.9m-7.3m (Ahmed, 2007). It therefore meets the requirements of accuracy in standard of Kenya.

Aerial photography makes a very useful data source due to their textural feature and superior spatial resolution. However, because of the cost of acquiring data and the time involved in analyzing large data sets in the aerial photographs, where the required information can be extracted from high resolution satellite imagery, it appears to be the most feasibly technology to adopt in land cadastral surveying. And where the use of the image presents its limitations, a combination of direct surveying methodologies and orthoimage identification can be made.

VI. CONCLUSSION

The principal objective of this study was to investigate the potential use of QuickBird orthoimage for use in cadastral surveying. To achieve this, comparisons of data from PID Area List, orthophoto and QuickBird orthoimage identification for different types of parcels were evaluated. Statistical tests carried out on the parcels indicated that there was no significant difference of areas between orthorectified aerial photographs and satellite image for computing areas for land adjudication. On the other hand, there was significant difference in areas between PID and orthophoto areas. The study has demonstrated that high-resolution satellite imagery with its utility to survey large areas at a time can be considered as an input for indirect land surveying methodology. This means that the re-fly process suggested by Adams (1969) as a means to upgrade the PIDs can be skipped for this alternative method. However, with regard to the minimum requirements for a Land Registry Index Map to be of sufficient accuracy to perform its core functions of parcel identification, boundary relocation, mutation surveys and area computation, it can be reasonably concluded that PIDs from QuickBird orthoimage met these requirements.

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