Accuracy Assessments of Differential Global Positioning System (DGPS) and High Resolution Satellite Image (HRSI) for Cadastral Surveying

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Abstract

Improvements in satellite technology have facilitated capturing of geometrically precise images of the earth's surface combined with DGPS technology for cadastral purpose. The study assess the use of Global Positioning System (DGPS) and High-Resolution Satellite Image for cadastral surveying. A 0.5 m (QuickBird Image) and Sokkia Differential Global Positioning System was used for the observation of control points and parcel delineation in static mode. Results showed differences in coordinates with a standard deviation of 0.18 m in Easting and 0.10 m in Northing respectively. Perimeter comparison result which shows a standard deviation value for DGPS as 5912.336 m2 and 5912.180 m2 for HRSI respectively, perimeter with a standard deviation value for DGPS as 163.121 m and 163.136 m for HRSI. Also, correlation coefficient analysis was carried out and the result obtained shows that the coordinate for both methods were correlated. It is worthy to conclude that the ground surveying method is still the most preferable method for cadastral surveying.

Keywords: Accuracy assessment, HRSI, DGPS, Cadastral Surveying

INTRODUCTION

Technology developments have revealed that GPS and satellite imageries with a high resolution can also be used for cadastral surveying (Yagol *et al.*, 2015). Cadastral mapping using GPS technologies and High-Resolution Satellite Imagery (HRSI) are progressively well-known in many developing countries of the world, replacing the conventional graphical surveying method (Yagol *et al.*, 2015). The accuracy between the cadastral data obtained by GPS technology is comparable with those acquired by conventional EDM/Total Station instrument for most cadastral purposes. The development of new satellite technologies have brought revolutionary changes in the area of GIS-based Cadastral Mapping system facilitating high-resolution satellite images of 0.6 m, 0.5 m or even 0.41 m spatial resolution (Ali, 2012). Creation and updating of cadastral maps, multifunctional cadastral data as land value maps and descriptions of the study area in an economical manner are some of the potential use of HRSI in Cadastral works (Ali *et al.*, 2012; Yagol *et al.*, 2015). HRSI such as QuickBird and IKONOS imagery is accurate enough for mapping purpose up to scale 1:5000 (Büyüksalih and Jacobsen, 2005). They however, do not suite for cadastral mapping at large scales, accepts integrated with ground cadastral survey techniques of precise GPS receivers and Total Station (Cay *et al.*, 2004). With continual studies and development of satellite image, techniques and systems developed have become more reliable, cheaper, faster, economical and more productive making satellite image more attractive for a range of surveying solutions.

A cadastral boundary is a discontinuity line on which the right of one party begins and the other ends (Zevenbergen, 2009). Cadastral boundaries may be natural or artificial and can be represented either by visible features on the ground, or bylines on a map or by coordinates (FIG and World Bank, 1995). According to Dale, and McLaughlin (1999), linear features such as fences and hedges can serve as cadastral boundaries in rural areas. Such visible boundaries are appropriate for many purposes in land management and land information systems (Zevenbergen and Bennett, 2015).

Cadastral Surveying practice policy is an organized and well-articulated document made by the surveyors in the state based on Surveyors' Council of Nigeria (SURCON) which has a set of guidelines, rules and regulations to control the practice of cadastral surveying within the states of Nigerian federation. These rules and regulations originated from CAP 194 of 1958 laws of the Federation of Nigeria and other survey laws. These laws have passed through series of amendments and repeals from then till date. The law establishing SURCON came to be in December 1989 as decree 44. This law was amended as CAP 425 of 1990 laws of the Federation. After the establishment of SURCON coupled with its empowerment with relevant provisions, a new set of rules and regulations were generally made at the national level with individual states and the Federal Capital Territory (FCT) to establish their own Cadastral Survey Policy (CSP) (Orisakwe, 2012).

Many states of the federation particularly those in the southern part of the country have since established and implemented their Cadastral Survey Practice Policy (CSPP) and have so far been guided by it. In these states State Ethics Committees (SEC) have been established, the Cadastral Survey Practice is well organized Orisakwe (2012). The common practice in Akure for cadastral surveying is based on the use of DGPS and Total Station instrument which is time consuming and costly. Hence the need for this study.

Land Information System (LIS) consists of spatial and non-spatial data. Both these spatial data (such as parcel boundary, shape, and location) and non-spatial data (such as ownership, rights, and area) are stored, maintained, and accessed in the database environment (Ali, 2012). Spatial data is acquired through cadastral surveys which are concerned with geometrical data of each land parcel. The results of cadastral surveys are isolated plans of a parcel or a subdivision. Cadastral mapping goes a step further and produces complete maps, which are based on cadastral surveys (Steudler, 2002). The cadastral survey system gives preference to the survey records of parcel boundary positions over physical locations of beacons on the ground. These records provide information with the coordinates of the beacons and site plans within a particular national geodetic reference system in a country. In case of the lost or disputed boundary of a land parcel, it is this record or register that takes the precedence over marks on the ground (Ali, 2012).

The existing cadastral surveying methods can be grouped into primary and secondary methods (Corlazzoli, 2004). In the case of the primary method, the relative position of points is located first on the ground, and the distance and angles are then measured using surveying instruments. Coordinates of positions and areas for each land plots are computed using mathematical formulae. On the other hand, in case of a secondary method, the surveyors use aerial photographs or satellite images to demarcate plot boundaries and the polygons are then digitized (Corlazzoli 2004; Ali, 2012). The cadastral surveying is carried out by three potential methods; (a) field survey, (b) aerial survey, and (c) satellite images. The first method comes under direct technique while the remaining two methods come within the indirect technique. This study adopted a field survey and satellite images methods.

Study area

The study area is Ijapo Estate located close to the Central Business District (CBD) Alagbaka, Akure in Ondo State, South West Nigeria. The layout has a total of 576 plots by design according to a drawing made available from the Ondo State Development and Property Corporation, (OSDPC) and 12 out of the plot were used for this study. The study area is located within Latitude 07º15’52”E and 07º16’04”E and Longitude 05º12’48”N and 05º13’00”N.

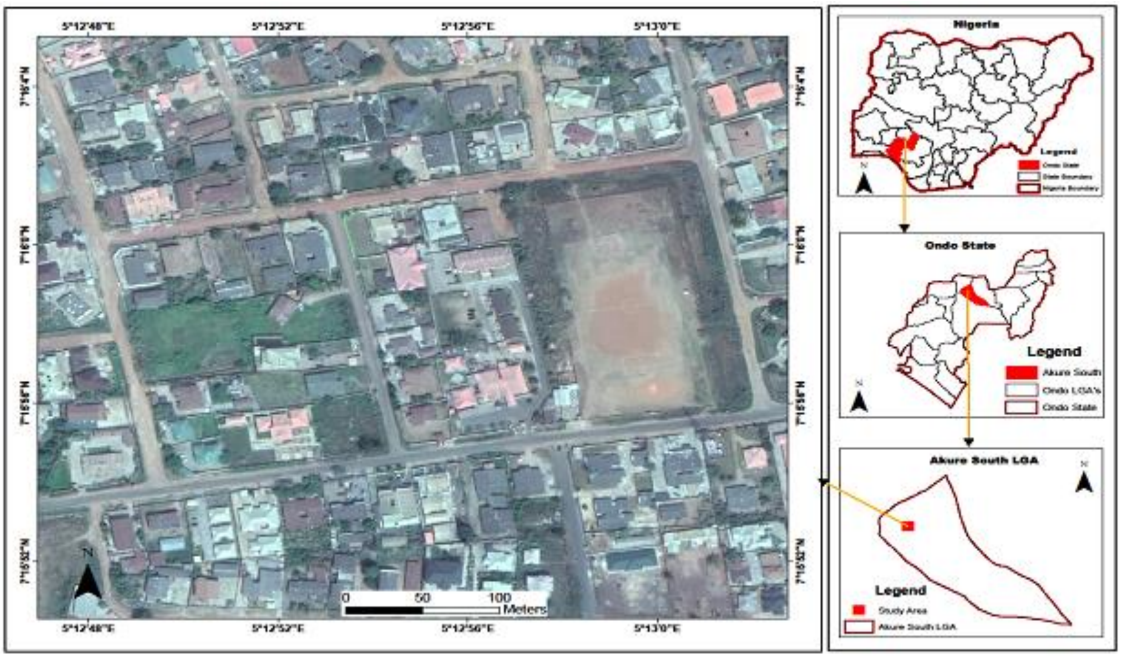

Figure1: Satellite image and map of the study area.

Methodology

The methodology flowchart adopted in this research is shown in (figure 2). A field survey was carried out using a Differential Global Positioning System (DGPS) to acquire coordinates of each fixed parcel boundary and Ground Control Points (GCPs) for geo-referencing when using the acquired QuickBird satellite image. After geo-referencing, cadastral boundaries for each of the plot were extracted via on screen digitization. Existing coordinate for the study area that is Record of Right (ROR) was collected from Ondo state Development and Property Corporation (OSDPC) for comparison with the acquired data from the field and digitized satellite image.

Data acquisition

The data used in this study include; Primary data (coordinate x, y) acquired using DGPS instrument and secondary data Quick-Bird (HRSI) and 0.6m spatial resolution image covering the study area obtained from the Department of Surveying and Geoinformatics, Federal University of Technology Akure. The existing layout plan, coordinate of the study area and existing coordinates of control points used for this study were obtained from the Ondo State Development and Property Corporation (OSDPC). DGPS was used to measure the position of points on the ground and also provided ground control points (GCPs) required for geo-referencing the satellite image and geometric correction during the pre-processing of HRSI. In order to locate its position, the receiver gets signals from at least four satellites which were maintained in this study for the better quality of data streaming. It involved direct field observation and measurement of hedges to obtain geometric data using a Sokkia GRX2 Differential Global Positioning System (DGPS) instrument. The acquired data were processed using Sokkia GRX2 utility software leading to the production of a cadastral survey plan.

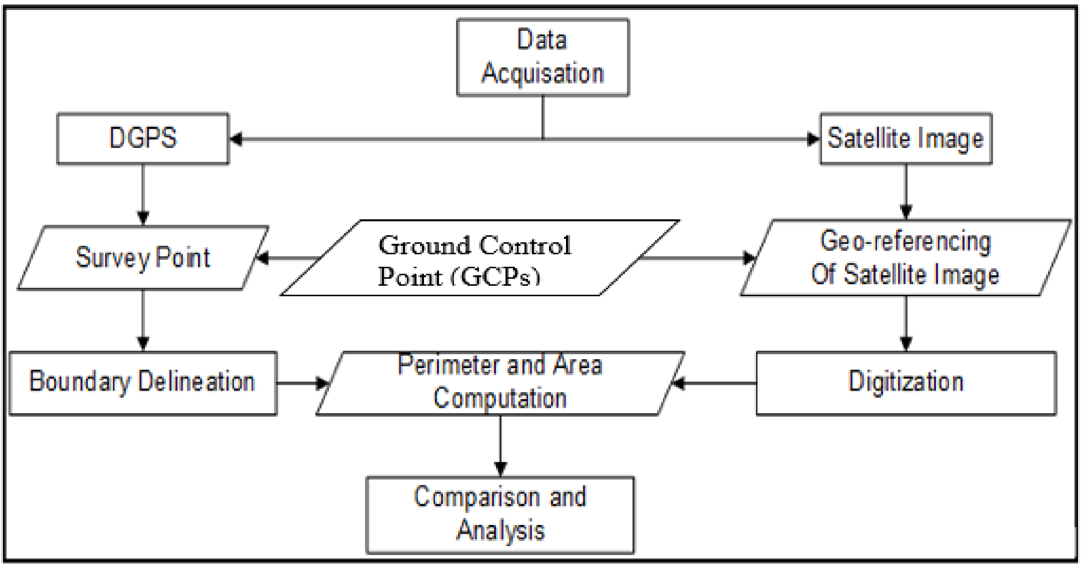

Figure 2. Methodology flowchart for the study. Ground

Data quality

Control check

Control checks are necessary where a surveying work is to be tied to reference points. This is to ascertain whether the control pillars are in-situ or not. From the check carried out it shows that the control pillars are *in-situ*.

Table 1: Control check data table

Name	Existing N(m)	Observed N(m)	Diff. (m)	Existing E(m)	Observed E(m)	Diff. (m)	Remark
GPS A72S	804138.569	804138.565	0.050	739356.656	739356.652	0.045	OK
GPS A73S	804138.569	804128.828	0.120	739142.409	739142.405	0.063	OK
GPS A74S	804386.036	804386.038	0.01	738768.701	738768.704	0.012	OK

Table 1 shows the level of satisfaction to which the work had been carried out. Though a lot of factors stand to impede the quality of the data this work had been carried out to ensure very high quality by using precise control point in for the fieldwork.

DGPS Observations

Being aware of the various sources of errors in all GPS observations, the study ensured that during the observation, canopy covering was avoided as much as possible for a better reception from satellites bearing in mind the Geometric Dilution of Precision (GDOP). The GDOP was monitored throughout the observation period to make sure that it was <=2. To avoid error from multipath, obstructions were avoided.

RESULTS AND DISCUSSION

Analysis using the Lot Area comparison

The total area for the study area acquired using Global Positioning System was 42574.052 Square meters while that of the digitized satellite image was 42588.768 Square meters respectively. The differences could have been as the result of error during digitalization or DGPS error. Figure 3 is the bar chart showing the comparison of the two methods adopted in the study.

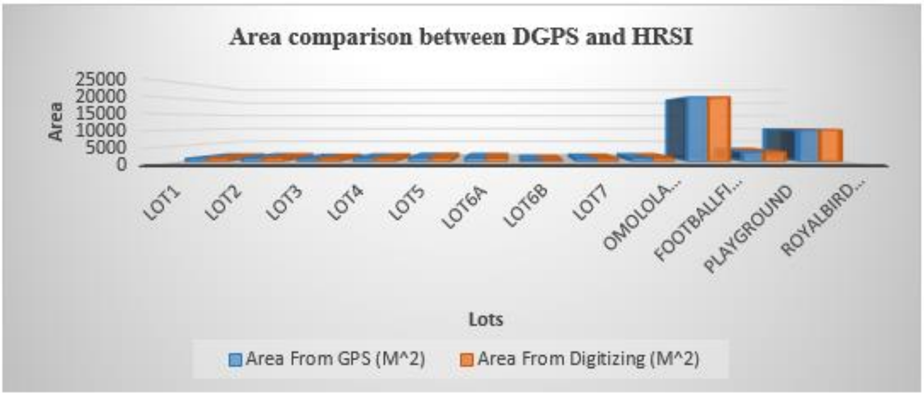

Figure 3: Bar chart comparison for DGPS and HRSI

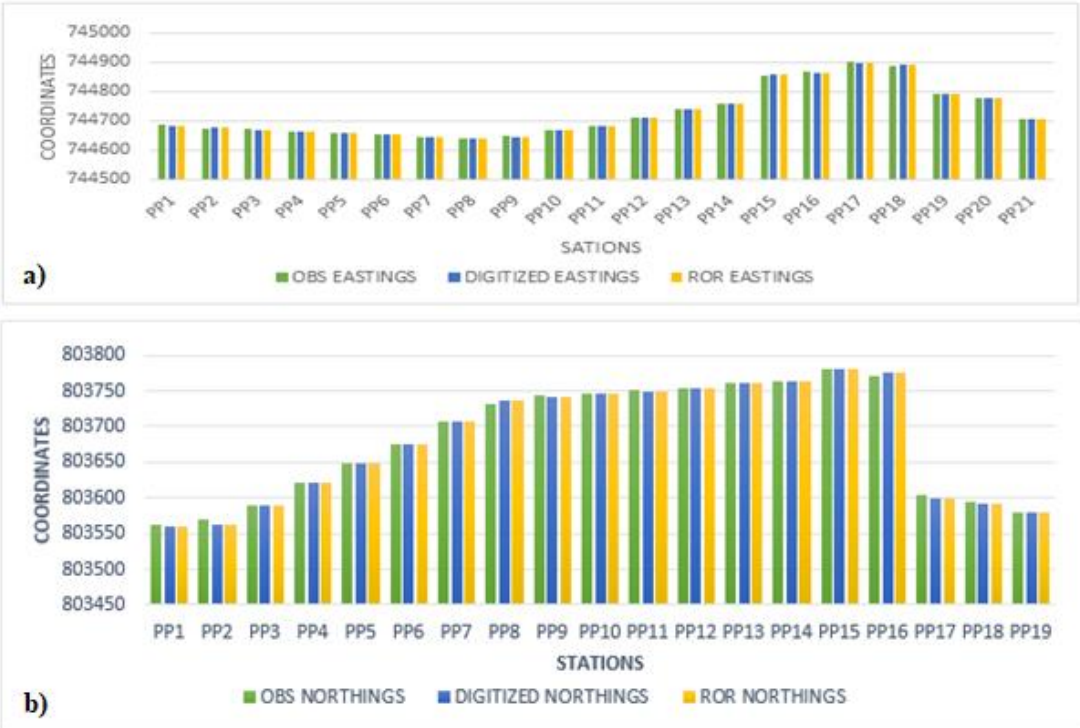

Figure 4: Comparison between GPS, Satellite Image and ROR in the a) Easting, b) Northings

Analysis using Coordinates comparison

The results in (figure 4a, b) show that the two sets of coordinates are close and their differences are within the acceptable international value of 1m according to (Toringe, 2013). The analysis of the result shows a standard deviation value of 0.10m in the easting coordinate and 0.10m in the northing coordinate respectively. This indicates that the northing coordinate is more precise than the easting coordinate.

Comparison using the Perimeters

The perimeter of the entire block and that of each of the lots were computed and compared. The result shows that; Perimeter from Record of Rights (ROR) was 806.666 m^2, Perimeter obtained using DGPS Observation was 820.588 m^2 and Perimeter obtained from the digitized satellite image was 820.587 m^2. A chart of comparison between the two methods is shown in (Figure 5).

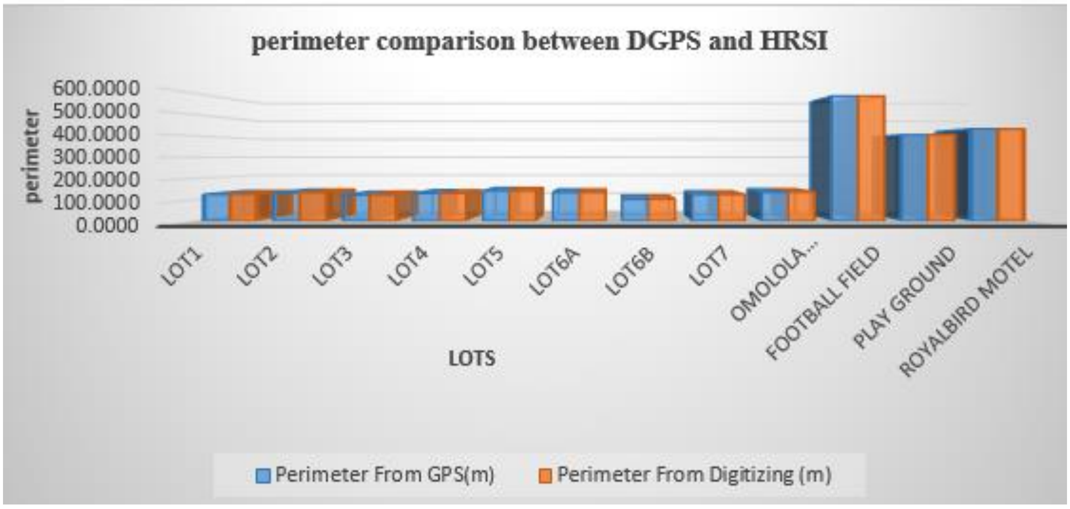

Figure 5. Bar chart showing Perimeters comparison between DGPS and HRSI.

Analysis using correlation coefficient

In correlation analysis, the values of correlation coefficient (r) lie between negative one (-1) and positive one (+1), when the value of r = to – 1, it indicate a perfect linear relationship with a negative slope. It also implies that there is a decrease in the Y axis and an increase in the X direction. When the values of r = to +1 it indicate a perfect linear relationship with a positive slope. This also means that there is an increase in both the Y and X axis.

The data used in the study were examined using correlation extension in micro soft excel. The observed Eastings and Northings using DGPS and the extracted Eastings and Northings form the digitized HRSI were correlated. The result in (Table 2) gave a correlation coefficient value of R^2 = 0.9999975 in the Northing coordinates while that of the Easting gave a value of R^2 = 0.99999703 respectively. The result shows that the values of R^2 are close to 1 which is an indication that the coordinates are well (highly) correlated in the eastings and northings (X and Y axis) directions.

The errors in Table 2 emanated from GPS observation due to cycle slip and probably GDOP during data streaming and digitizing of plots due to issues of indistinct boundaries due do similar ghostly reflectance.

Table 2. Coordinate differences

POINTS	Eastings (m) DGPS	Eastings (m) HRSI	Diff (m)	Northings (m) DGPS	Northings (m) HRSI	Diff (m)	Position Diff (m)
PP1	744679.848	744679.849	-0.001	803560.592	803560.588	0.004	0.000
PP2	744675.323	744675.164	0.159	803563.400	803563.502	-0.102	0.025
PP3	744668.322	744668.326	-0.004	803590.361	803590.362	-0.001	0.000
PP4	744661.92	744661.917	0.003	803622.506	803622.506	0.000	0.000
PP5	744656.639	744657.346	-0.707	803647.721	803647.965	-0.244	0.503
PP6	744651.073	744651.057	0.016	803675.272	803675.269	0.003	0.000
PP7	744643.684	744643.568	0.116	803706.367	803706.146	0.221	0.016
PP8	744637.531	744637.207	0.324	803735.966	803735.771	0.195	0.106
PP9	744641.845	744641.844	0.001	803742.330	803742.328	0.002	0.000
PP10	744668.691	744668.691	0.000	803747.398	803747.398	0.000	0.000
PP11	744683.463	744683.463	0.000	803749.998	803749.998	0.000	0.000
PP12	744709.007	744709.025	-0.018	803754.693	803754.697	-0.004	0.000
PP13	744740.203	744740.203	0.000	803760.682	803760.682	0.000	0.000
PP14	744756.182	744756.182	0.000	803763.381	803763.381	0.000	0.000
PP15	744856.514	744856.517	-0.003	803780.332	803780.335	-0.003	0.000
PP16	744863.575	744863.575	0.000	803775.441	803775.441	0.000	0.000
PP17	744897.996	744897.996	0.000	803598.402	803598.402	0.000	0.000
PP18	744893.183	744893.184	-0.001	803591.799	803591.799	0.000	0.000
PP19	744791.958	744791.958	0.000	803579.691	803579.691	0.000	0.000
PP20	744775.866	744775.866	0.000	803577.795	803577.795	0.000	0.000
PP21	744707.402	744707.484	-0.082	803565.505	803565.327	0.178	0.008
Mean	744726.7	744726.69	-0.0094	803670.93	803670.923	0.0119	0.0314
Std	87.0066	87.005076	0.18015	84.249271	84.2389343	0.0963	0.1107
Var	7570.148	7569.8833	0.03245	7097.9397	7096.19804	0.0093	0.0122
R^2	0.999997857			0.999999354			

Analysis using time comparison

Using the time of completion as a comparison factor, the ground survey work when using Global Positioning System took five (5) days for its completion based on the fact that field observations were required which consumed more time and cost while that of the High-Resolution Satellite Image took three (3) days for the fieldwork which was less, economical and consumed lesser time. This implies that producing a cadastral map using a satellite image is faster compared to that of the ground survey method using a Global Positioning System.

CONCLUSION AND RECOMMENDATIONS

The study has shown good potentials on the use of HRSI image and DGPS for cadastral surveying. This study integrates the probability of adopting HRSI for an indirect method of cadastral surveying to achieve high precision with low cost and within an appropriate time. In this report accuracy assessments of DGPS and High-Resolution Satellite Image for cadastral surveying have been discussed extensively. A comparison between parcel boundaries acquired from the two techniques was carried out and proved to be effective and useful for cadastral surveying. Various components of the derived parcel such as Area with a standard deviation value for DGPS as 5912.180m2 and 5912.336m2 for HRSI respectively, perimeter with a standard deviation value for DGPS as 163.121m and 163.136 for HRSI respectively and period for both methodologies adopted were compared alongside human resources involved.

Correlation coefficient analysis was carried out on the coordinate for the two techniques and the result shows highly correlated. The comparisons show that parcel boundaries can be determined with acceptable precision and accuracy meeting the requirement for cadastral surveying. It was also discovered that the use of HRSI will ease updating cadastral maps more suitably and economically. Although the determined results from the two techniques in parcel boundaries delineation show good potential for HRSI use in the cadastral survey, a reliable accuracy cannot be achieved as compared to that of GPS reason been that satellite method solely depends on visual interpretation. There could also be issues of indistinct boundaries due to similar ghostly reflectance and small parcel; as such, similar accuracy cannot be achieved. Therefore, care must be taken when georeferencing and digitizing satellite imageries for cadastral survey purpose.

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