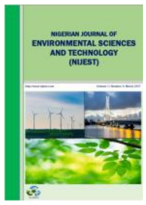
Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2734-259X | ISSN (electronic): 2734-2603
Vol 6, No. 1 March 2022, pp 234 - 245



Comparative Analysis of the Horizontal Positional Accuracy of Google Earth and Bing Imageries of Samaru, Kaduna State-Nigeria

Youngu T. T.[1,*], Aliyu Y. A.[2], Azua S.[3], Bawa S.[4], Bala A.[5] and Hamzat H. D.[6]
[1,2,3,4,5,6]Department of Geomatics, Ahmadu Bello University, Zaria, Nigeria
Corresponding Author: *terwasey2000@gmail.com; ttyoungu@abu.edu.ng

https://doi.org/10.36263/nijest.2022.01.0341

ABSTRACT

Satellite imageries have in the recent past gained popularity in the areas of geo-informatics and geo-positioning due to the fact that they provide global coverage and are cost-effective. Nevertheless, the use of these services poses questions on their spatial data quality in terms of positional reliability and accuracy, which have implications on their applicability. This study therefore, analyzed the horizontal positional accuracy of satellite imageries (Google Earth and Bing) of Samaru in Kaduna state, Nigeria. The coordinates of 63 ground points (GPs) acquired with the Total Station instrument (Leica TCA 1201 M) were assessed against their corresponding points on the imageries using simple statistical accuracy metrics. The results revealed that the root mean square error (RMSE) of positions on the ground were significantly different from the RMSE of positions on the Google Earth and Bing imageries only in the Easting direction at the 95% significance level when p (2-tailed) = 0.000 [p < 0.05]. The study revealed that 50% and 70% of the Easting and Northing coordinates of the Google Earth imagery were related to the corresponding ground coordinates. In addition, 51% and 67% of the Easting and Northing coordinates of the Bing imagery were related to the corresponding ground coordinates. The results also showed that the Google Earth and Bing imageries had an overall positional accuracy of 6.09 m and 6.02 m, respectively, with the latter being more reliable in determining horizontal positions in the study area. The accuracy obtained was sufficient for navigation purposes and ground-based measurements that do not require very high accuracy. It was suggested, however, that a geometrical accuracy evaluation of similar or different imageries of the same study location or a more complex terrain should be undertaken to determine their reliability.

Keywords: Geo-positioning, Mapping, Positional reliability, Satellite imagery, Spatial data

1.0. Introduction

There has been an increase in the interest and demand for the use of satellite imaging products for positioning and scientific research purposes as a result of the fact that they provide vast coverage with speed and cost-effectiveness. They can also provide data in areas that were previously inaccessible to other traditional methods of data acquisition, such as field surveys. Moreover, satellite imageries with the appropriate spectral and spatial resolutions (Campbell, 2002), can be used for urban development plans in the assessment of natural resources, land use monitoring, planning, and map-making (Khalaf *et al*., 2018).

Satellite imageries especially the high resolution satellite imageries (HRSIs), are, however, usually expensive to acquire due to the fact that certain companies sell these imageries by licensing them to governments and businesses such as Apple Maps and Google Maps (Madrigal, 2012). The advent of HRSIs such as IKONOS, EROS-A1, Quick Bird, and Orbview-3, among others, with spatial resolutions ranging from 1.8 m to 0.6 m since 1999 has changed the usability and applicability of spatial data obtained from space-based photogrammetry (Brovelli *et al*., 2006).

There is no doubt that satellite earth observations can benefit many areas of society, including environmental and resource management, agriculture and food security, transportation, air quality and health, risk management, and security (Lafaye, 2017). However, these imageries may prove ineffective, especially when their accuracy has not been verified as compared to the traditional method of gathering positional data. Besides, the use of satellite imageries requires that they be oriented in a particular reference frame and corrected for terrain relief, distortions, and displacements, and, of course, with the use of control points, in order to become an effective tool in different earth applications (Okeke, 2010). Against this backdrop, some research efforts on the positional accuracy of satellite images have been made in the past.

Brovelli *et al.* (2006) assessed the accuracy of QuickBird and Eros-Al imageries using the method of leave-one-out cross validation (LOOCV) for the orientation and ortho-rectification of the imageries with known ground points. The study revealed the residual between the imagery derived coordinates and their corresponding ground point coordinates. It also showed the overall spatial accuracy in terms of the root mean square error (RMSE) and median absolute deviation (mAD). The method proved to be reliable and applicable in areas where there was limited number of control points.

Cuartero *et al.* (2010) evaluated the positional accuracy of the TERRA-ASTER images of the Extremadura area of Spain by Circular Statistics. The errors in the positional accuracy of geometric corrections of satellite images using independent check lines (ICLs) were analyzed instead of the independent check points (ICPs). The ground control point (GCP), ICP, and ICL data of the study area were acquired during a field survey by differential GPS, and the planimetric positional accuracy was analyzed by both the conventional method (using ICP) and the proposed method (using ICL). The results of comparing the two methods showed that the RMSE of geometric correction was 17.5 m and 17.2 m for the conventional and proposed methods.

Pulighe *et al.* (2015) carried out the horizontal accuracy assessment of very high resolution Google Earth (GE) images of the city of Rome, Italy. The images were ortho-rectified using 41 GCPs acquired from GPS field survey campaigns. The results showed that the GE images had an overall positional accuracy of nearly 1 m. The result of the study showed its applicability to ground-based measurements and planimetric mapping.

Zheng *et al.* (2018) evaluated the geometric accuracy of multiple HRSIs (SPOT-6, Pleaides, ALOS, ZY-3, and TH-1) in the Xianning test field in China. The GCPs of the study area were acquired during GPS field surveys. The results of the orientation of the geometrical performance of the HRSIs showed that Pleaides and SPOT6 performed with the highest accuracy without GCPs, and the interior geometric accuracy of TH-1 was poor. However, there were no significant changes to the geometric accuracy when more GCPs were added.

Other studies that evaluated the positional accuracy of satellite images in relation to ground points include (Ubukawa, 2013; Jeong *et al*., 2015; Gim and Shin, 2016; Jiao *et al*., 2018; Mulu and Derib, 2019), among others. The assessment of the positional accuracy of satellite imageries with respect to the ground control points obtained from ground surveys will provide a useful guide to the suitability and reliability of remotely sensed data from selected satellite image providers (SIPs) before they are utilized in various applications such as mapping, engineering work, and other purposes. This study therefore evaluates statistically the reliability of the horizontal positions of affordable and readily available satellite images (Google Earth and Bing) of the study area with their corresponding ground positions.

1.1. Study area

The study area is located in the Samaru area of Zaria, Kaduna State, Nigeria between latitude [11°8’20" and 11° 8’19.84"] N of the Equator and longitude [7°37’17.83" and 7° 38’32.48"] E of the central meridian. Figure 1 depicts the study area.

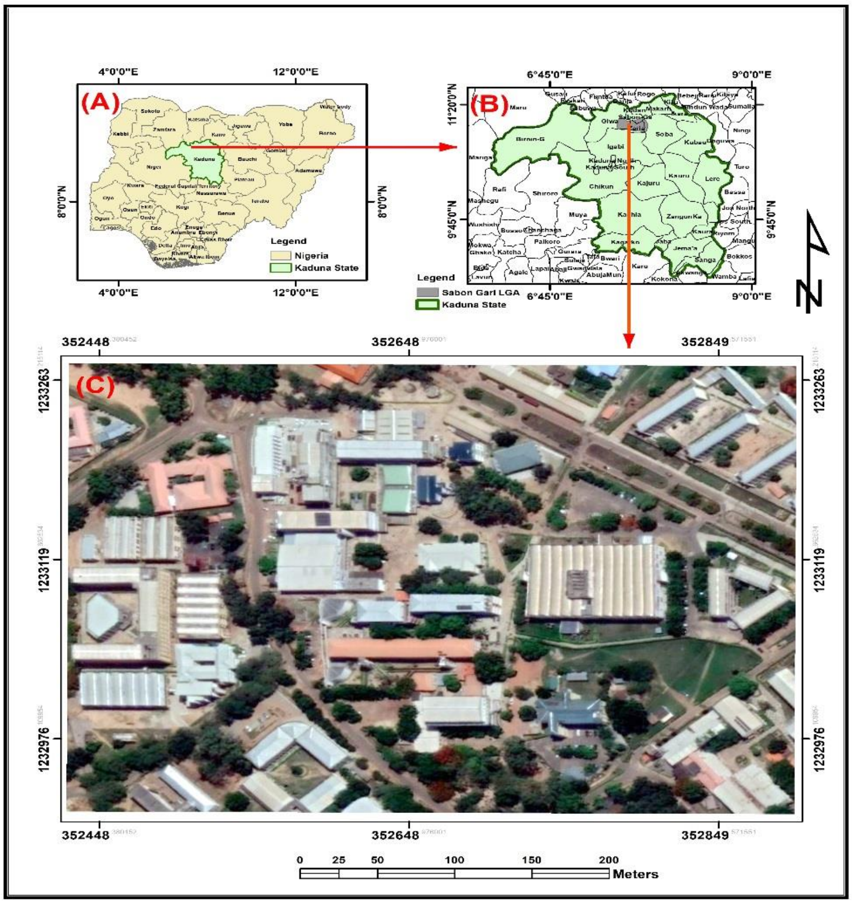


Figure 1: The study area; (a) Nigeria, (b) Kaduna state, and (c) Study location

It has a tropical savannah climate with warm weather year-round, a wet season lasting from April to September, and a dry season from October to March. The average temperature for the year in the study area is 78.0° F (25.6° C) (Climate-Data, 2019). The bedrock geology is predominantly metamorphic rocks of the Nigerian basement complex, consisting of biotic gneisses and older granite (Mortimore, 1970). It is a growing semi-urban settlement with an estimated population of 393,300 based on the National Population Commission of Nigeria's 2006 census and the National Bureau of Statistics (City Population, 2016). The major occupations of the people are trading, farming, artisanship, and civil service (Ogenyi, 2010).

The methodology adopted in this study included the planning and reconnaissance, data acquisition, data processing, analyses, and results stages as presented in a simplified workflow diagram (see Figure 2).

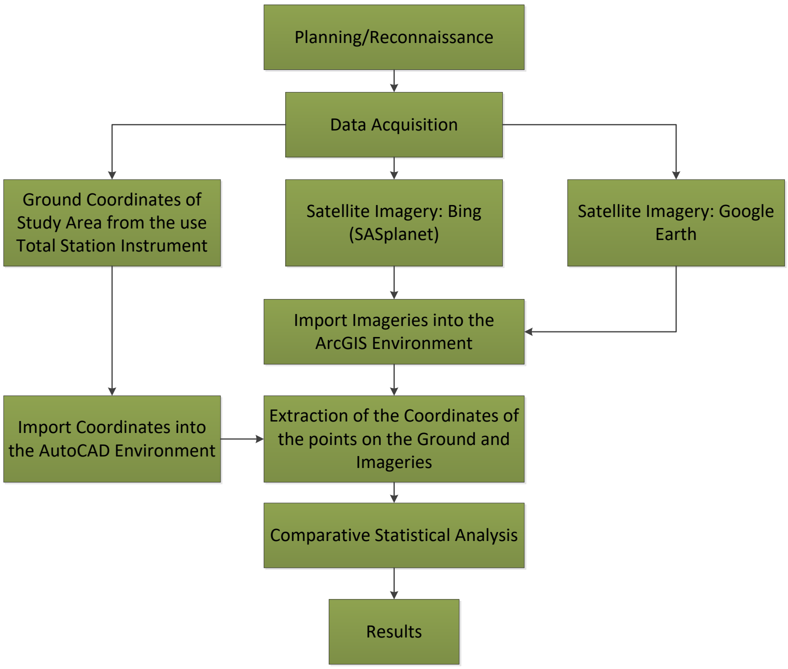


Figure 2: Workflow diagram

2.0. Methodology

2.1. Data sources

The details of the datasets and their sources utilized in this study are described in Table 1.

Table 1: Datasets and sources

S/N	Data	Type	Source and Date	Location	Resolution
1	Ground Coordinates	Primary	Field survey (07-10-2021)	Samaru	N/A
2	Google Earth imagery	Secondary	http://www.sasgis.org/sasplaneta/ (05-10-2021)	Samaru	15 m
3	Bing imagery	Secondary	http://www.sasgis.org/sasplaneta/ (05-10-2021)	Samaru	18 m

2.2. Planning/reconnaissance

The planning stage involved both the office and field reconnaissance where the appropriate site was selected based on the existing maps and plans, the number of points as GCPs to be surveyed and the survey method were determined. It also considered logistics requirements as well as cross-checking the information acquired.

2.3. Data acquisition

The coordinates of sixty-three (63) points [52 points aligned with the edges of roofs considering image distortion, shadow, tilt, and so on, and 11 ground points] corresponding to the points on the Google Earth and Bing imageries were acquired using a Total Station instrument (Leica TCA 1201 M) with the capability of measuring angles to 0.5 arc-second and distances up to 1,500 metres (4,900 ft.) with an accuracy of about 1.5 millimetres (0.059 in) ± 2 parts per million. This is consistent with the general accuracy levels for surveying and building construction grade instruments in urban environments (Leica Geosystems, 2008). The Google Earth and Bing imageries were acquired using the SAS Planet download software version 2021.

2.4. Data processing

The data acquired from the field survey was transferred into Microsoft Excel (2013) on a computer system (Hp, CORE i5, 4GHz processor, 8GH RAM, 500GB HDD). The dataset was then exported into the AutoCAD software (2016 version) where the coordinates were plotted to obtain the perimeter of the study area. The acquired Google Earth and Bing imageries with their corresponding ground coordinates (E, N) were imported into the ArcGIS 10.3 environment where they were geo-referenced using the ground coordinates and the reference system (WGS 84, UTM zone 32N) was defined.

3.0. Results and Discussion

3.1. Corresponding points

Tables 2 and 3 provide the difference between selected ground points (7 out of the 63 points acquired) and corresponding points on the Google Earth (GE) and Bing imageries, respectively.

Table 2: Difference between selected corresponding ground points and points on GE image

S/N	Station ID	Ground		Google Earth		Difference	
		Easting (m)	Northing (m)	Easting (m)	Northing (m)	Easting (m)	Northing (m)
1	Mec1	352609.15	1233287.19	352608.95	1233233.81	0.2	53.38
2	EE1	352546.86	1233170.39	352554.89	1233167.75	8.03	2.64
3	EE2	352581.29	1233163.25	352567.25	1233167.64	14.04	4.39
4	EE3	352593.35	1233163.28	352589.21	1233160.01	4.14	3.27
5	Cv1	352562.37	1233152.82	352567.04	1233150.73	4.67	2.09
6	Cv2	352557.83	1233145.13	352561.33	1233137.61	3.5	7.52
7	Cv3	352557.86	1233144.13	352561.88	1233133.48	4.02	10.65

The results of Table 2 show that the least deviations in the Easting and Northing directions were at points Mec1 (0.20 m) and Cv1 (2.09 m), when the coordinates of the GE imagery were compared to the corresponding points on the ground. However, the largest deviations in the Easting and Northing directions were at the points EE2 (14.04 m) and Mec1 (53.38 m), when the corresponding ground and GE imagery points were compared. Meanwhile, the average deviations in the Easting and Northing directions are 5.48 m and 12.18 m.

Table 3: Difference between selected corresponding ground points and points on Bing image

S/N	Station ID	Ground		Google Earth		Difference	
		Easting (m)	Northing (m)	Easting (m)	Northing (m)	Easting (m)	Northing (m)
1	Mec1	352609.15	1233287.19	352608.95	1233233.81	4.4	52.68
2	EE1	352546.86	1233170.39	352554.89	1233167.75	13.45	15.61
3	EE2	352581.29	1233163.25	352567.25	1233167.64	7.75	4.78
4	EE3	352593.35	1233163.28	352589.21	1233160.01	1.68	1.54
5	Cv1	352562.37	1233152.82	352567.04	1233150.73	7.7	1.86
6	Cv2	352557.83	1233145.13	352561.33	1233137.61	12.6	17.98
7	Cv3	352557.86	1233144.13	352561.88	1233133.48	13.23	7.59

The results of Table 3 indicate that the least deviations in the Easting direction (1.68 m) and Northing direction (1.54 m) are at point (EE3) when the coordinates of the Bing imagery were compared to the corresponding ground points. When the corresponding ground and Bing imagery points were compared, the most deviations in the Easting and Northing directions were at points EE1 (13.45 m) and Mec1 (52.68 m). However, the average deviations in the Easting and Northing directions were 6.03 m and 15.19 m.

Figures 3 and 4 show the corresponding points (52 roof edges and 11 ground points) identified on the GE and Bing imageries, respectively.

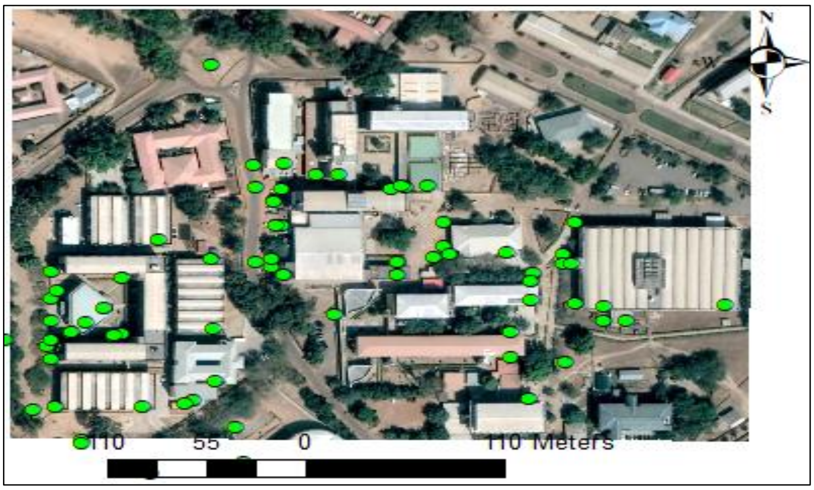


Figure 3: Ground points on the Google Earth imagery

The geo-referenced Google Earth and Bing images were used to identify the positions of the corresponding ground points in the ArcGIS environment.

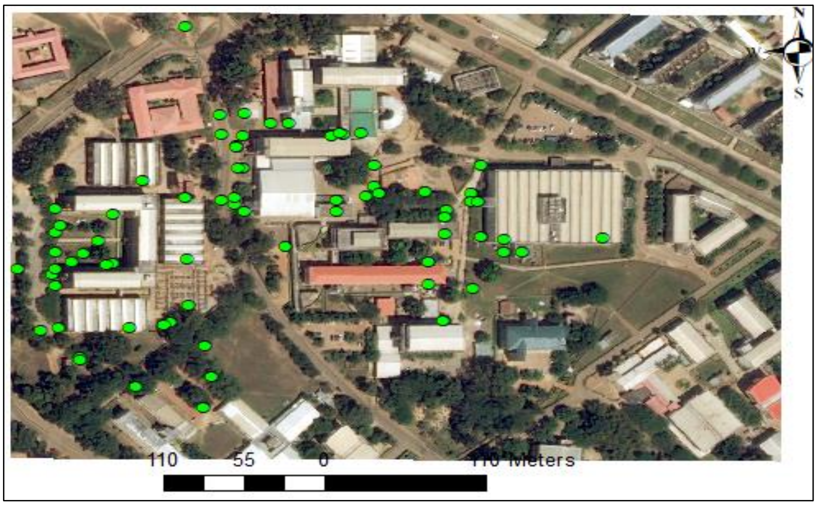


Figure 4: Ground points on the Bing imagery

3.2. Horizontal accuracy

The greatest possible amount of error realized from a measurement or process at a probability level of 95% clearly describes accuracy (Congalton and Green, 2009). Meanwhile, the difference between the coordinates of a feature located on an image and the coordinates of its true location on the ground describes the positional accuracy of spatial data (Goodchild and Hunter, 1997). The magnitude of the absolute errors of Google Earth and Bing images were calculated using simple statistical accuracy metrics. Absolute accuracy is expressed as the horizontal root mean-square error (RMSE) of residuals between imagery derived coordinates and ground coordinates, which consists of both random and systematic errors introduced in the course of acquiring data (ASPRS, 1990). The RMSE expresses the frequency measure of the difference between two variables as follows (Pulighe *et al.*, 2015):

$$RMSE = \pm\sqrt{\frac{\sum_{i=1}^{n}(Ai - Fi)^2}{n}} \quad (1)$$

Where;
RMSE is the root mean square error;
Ai is the ground coordinate at the point i;
Fi is the satellite coordinate at point i;

n is the number of point observations.

The Root-Mean Square Error (RMSE) obtained for both images is shown in Tables 4 and 5. The planimetric accuracy evaluation was carried out first by using a set of 63 well-defined points that were identified on the Google Earth and Bing images, respectively, for their measured coordinates. The error in each point is the difference between the location of each point on the image and its corresponding ground coordinate.

Table 4: Statistical difference between ground coordinates and the corresponding points on the Google Earth image in the Easting and Northing directions

Basic statistics	Google earth dx	Google earth dy
Mean	-4.059	-5.767
Standard Error	1.875	5.912
Standard Deviation	13.123	41.382
Sample Variance	172.207	1712.457
Kurtosis	7.901	18.599
Skewness	1.582	-3.697
Range	85.834	291.690
Minimum	-39.155	-231.241
Maximum	46.679	60.449
Sum	-198.894	-282.585
Count	49	49
Confidence Level (95%)	3.526	32.811
RMSE	1.905	5.790
RMSE(dxy)		6.095

Google earth dx is the error in Easting; Google earth dy is the error in Northing; RMSE (dxy) is the overall RMSE for the Google Earth imagery

Table 4 shows the mean, minimum, maximum, and RMSE values along the Easting (dx) and Northing (dy) directions for the Google Earth image. The RMSE values along the Easting and Northing were derived as 1.905 m and 5.790 m.

The overall root mean square error (RMSEdxy) was derived as 6.095 m using the following (Pulighe *et al.*, 2015):

$$\sqrt{RMSE_{dx}{}^{2} + RMSE_{dy}{}^{2}} \tag{2}$$

Where;
$RMSE_{dx}$ is the Easting root mean square error
$RMSE_{dy}$ is the Northing root mean square error.

The coefficients of skewness and kurtosis for the Google Earth imagery gave low Easting values (see Table 4) which can be considered to be evenly distributed, and gave high Northing values which can be considered to be unevenly distributed (Daniel and Tennant, 2001).

Table 5: Statistical difference between ground coordinates and the corresponding points on the Bing image in the Easting and Northing directions

Basic statistics	Bing dx	Bing dy
Mean	-7.965	-3.917
Standard Error	1.864	5.785
Standard Deviation	13.048	40.497
Sample Variance	170.243	1640.042
Kurtosis	7.150	21.645
Skewness	1.663	-4.071
Range	85.104	293.200
Minimum	-44.835	-232.141
Maximum	40.269	61.059
Sum	-390.283	-191.9551
Count	49	49
Confidence Level (95%)	3.74774501	42.38874633
RMSE	2.124	5.638
RMSE(dxy)		6.025

Bing dx is the error in Easting; Bing dy is the error in Northing; RMSE (dxy) is the overall RMSE for the Bing imagery

Table 5 shows the mean, minimum, maximum, and RMSE values along the Easting (dx) and Northing (dy) directions for the Bing image. The RMSE along the Easting and Northing were derived as 2.124 m and 5.638 m. The overall RMSE obtained is 6.025 m. The coefficients of skewness and kurtosis for the Bing image gave low Easting values, which can be considered to be evenly distributed, as they gave high Northing values, which can be considered to be unevenly distributed. This also could have been a result of systematic error due to the transformation of the reference system.

3.3. Test for significant difference

The test for a significant difference between the RMSE for positions obtained in the study area with regards to the Google Earth and Bing imageries was rationalized using the IBM SPSS software (version 2.0). The mathematical formulae for the paired sample T-test are as follows (Tutorvista, 2021):

$$t = \frac{\bar{d}}{S\epsilon(\bar{d})} \tag{3}$$

The null and alternate hypotheses are as follows:
H_0= D = 0 ≡ there is no significant difference between the RMSE for positions in the Google Earth and Bing imageries.
H_I = D≠0 ≡ there is significant difference between the RMSE for the positions in the Google Earth and Bing imageries.
Where, $\bar{d}$ is the mean difference of paired observations; S$\epsilon(\bar{d})$ is the standard error of the mean difference of paired observations with n-1 degrees of freedom.

If the calculated value of t for the deviations along the north-south dimension (ΔN), $/t_N/$ is less than the table value $t_{n-1},{}^{\alpha}/_{Z}$ and the calculated value of t for deviations in the east-west dimension (ΔE), $/t_E/$ is less than $t_{n-1},{}^{\alpha}/_{Z}$ then the generated product (for example, image) is free from systematic errors in the Easting and Northing directions.

Table 6 shows the results of the paired sample t test to determine whether there is a significant difference between the RMSEs of positions for the GE and Bing images with respect to the ground points.

Table 6: Paired sample t test

Difference	Mean	Std. Deviation	Std. Error	95% CI Upper & Lower	T	Sig.(2-tailed)
Diff. btw Ground & GE Coordinates (E) - Diff. btw Ground & Bing Coordinates (E)	3.905	6.493	.928	5.771 2.041	4.21	.000
Diff. btw Ground & GE Coordinates (N) - Diff. btw Ground & Bing Coordinates (N)	-1.849	12.256	1.751	1.671 -5.369	-1.05	.296

The t value is -1.056 in the Northing direction for the difference between the ground and the Google Earth image, and the difference between the ground and the Bing image. Also, the t value is 4.211 in the Easting direction for the difference between the ground and the Google Earth image, and the difference between the ground and the Bing image. The results revealed a significance value (2-tailed) of 0.296 and 0.000 in the Northing and Easting directions. Since the significance value obtained (0.000) is less than the p value (0.05) [$p < 0.05$] in the Easting direction, we reject the null hypothesis and accept the alternative hypothesis. Hence, there is a significant difference between the RMSEs in the Easting direction. In addition, since the significance value obtained (0.296) is greater than the p value (0.05) [$p > 0.05$] in the Northing direction, we accept the null hypothesis and reject the alternative hypothesis.

3.4. Evaluation of positional horizontal accuracy

Figure 5 shows the relationship between the Easting of the Google Earth (GE) points and ground points.

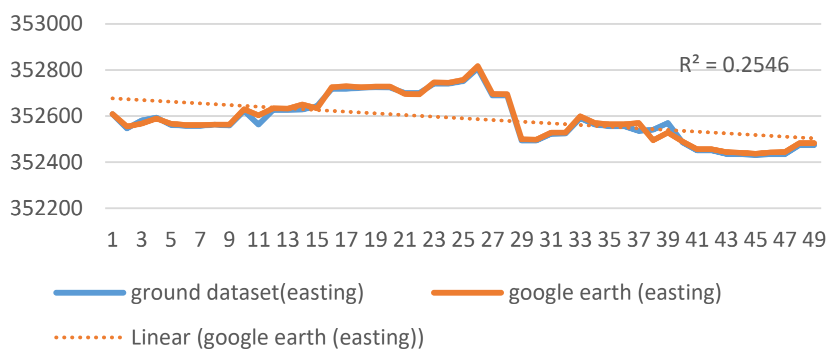


Figure 5: Relationship between the GE points (Easting) and ground points (Easting)

The Easting of the GE can be observed to assume a similar pattern to that of the ground points, but with a slight variation in their positioning. However, the correlation coefficient (r = 0.5046) indicates that the strength of the association between the two variables is moderate.

Figure 6 shows the relationship between the Northing of the Google Earth (GE) points and ground points.

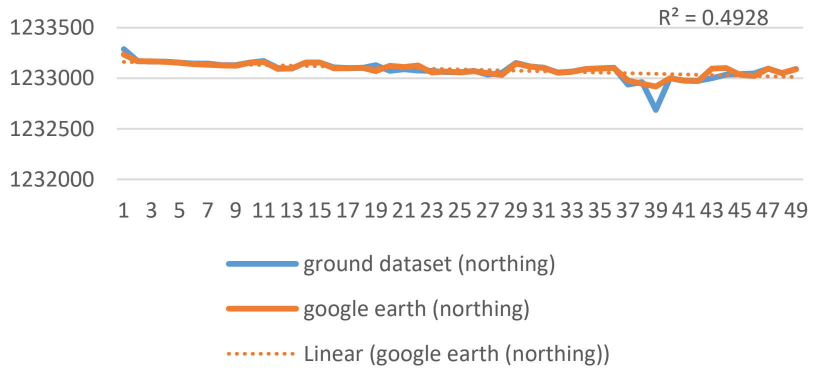


Figure 6: Relationship between the GE points (Northing) and ground points (Northing)

The Northing of the GE points can be observed to assume a similar pattern to that of the ground points, but with some of the points observed to deviate a little from that of the ground points. The coefficient of correlation (r = 0.7014) indicates a strong association between the two variables.

Figure 7 shows the relationship between the Easting of the Bing points and ground points.

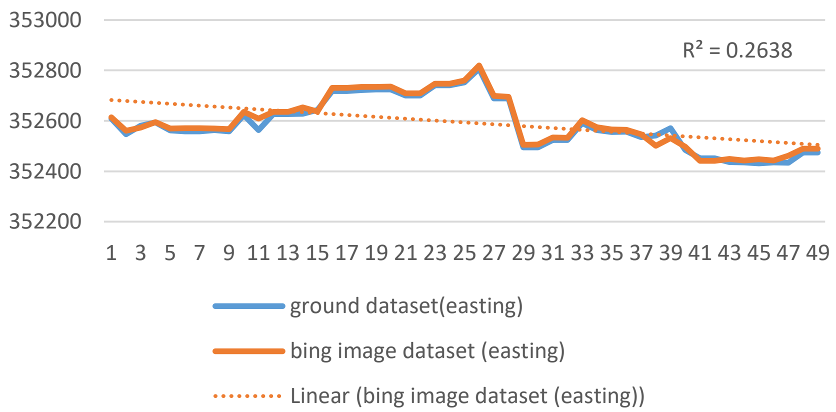


Figure 7: Relationship between the Bing points (Easting) and ground points (Easting)

The Easting coordinates of the Bing points have the same form as that of the ground points but are slightly different in positioning. Meanwhile, the coefficient of correlation (r = 0.5136) shows a moderate strength of association between the two variables.

Figure 8 shows the relationship between the Northing coordinates of the Bing and ground points. The Northing coordinates of the Bing points have a similar form to that of the ground points and some of the deviating points. The coefficient of correlation (r = 0.6729) indicates a slightly stronger strength of association between the two variables.

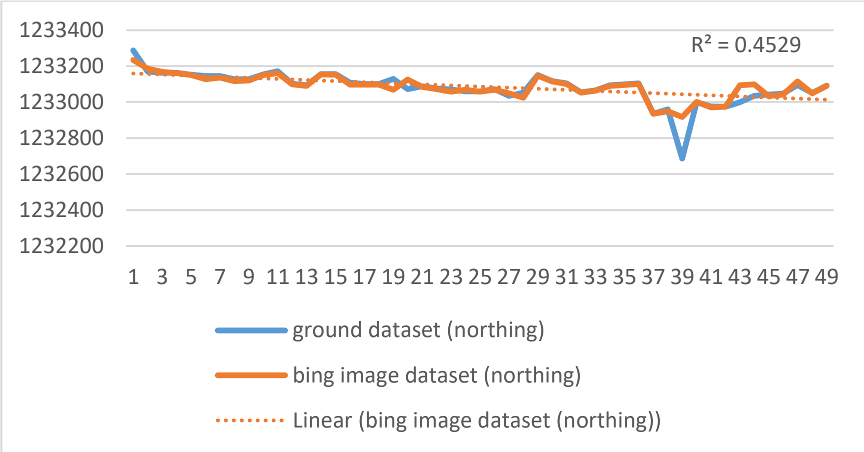


Figure 8: Relationship between the Bing points (Northing) and ground points (Northing)

The Northing coordinates of the Bing points have a similar form to that of the ground points and some of the deviating points. The coefficient of correlation (r = 0.6729) indicates a slightly stronger strength of association between the two variables.

The results of this study revealed that the RMSEs of the Google Earth image were 1.905 m and 5.790 m in the Easting and Northing directions. It also revealed that the RMSEs of the Bing image were 2.124 m and 5.638 m in the Easting and Northing directions. Meanwhile, the overall RMSEs of the Google Earth and Bing images were 6.095 m and 6.025 m. The difference in accuracy in terms of the overall RMSE between the Google Earth and Bing images was 0.07 m. The findings of this study reveal a slightly better positional accuracy in terms of the RMSEs than with Ubukawa (2013) but agree with it in the evaluation of positional horizontal accuracy and with Pulighe *et al*. (2015) for the purpose of deriving ground truth samples.

The results also showed that there was a significant difference in the Easting coordinates when the Google Earth and Bing points were compared to the ground points. However, there was no significant difference in the Northing coordinates when the Google Earth and Bing points were compared to the ground points. The implication, therefore, is that systematic errors exist in the Easting direction when the Google Earth and Bing imageries are compared with respect to the ground points. However, when the two imageries were compared with respect to the ground points in the Northing direction, they were free or had little systematic errors. The results showed that the average deviations in the Easting and Northing directions were 5.48 m and 12.18 m, when the coordinates of the GE imagery and ground points were compared, and 6.03 m and 15.19 m, when the coordinates of the Bing imagery and ground points were compared. The study revealed that about 50% and 70% of the Easting and Northing coordinates of the GE imagery are related to the corresponding ground coordinates. In addition, about 51% and 67% of the Easting and Northing coordinates of the Bing imagery are related to the corresponding ground coordinates. The findings of this study tend to agree with Brovelli *et al*. (2006) as it can be applied in areas where the number of ground points is sparse. The field survey of this study was carried out with a Total Station which is different from that conducted by Jeong *et al*. (2015); Zheng *et al*. (2018); and Mulu and Derib (2019) who adopted the differential GPS method.

4.0. Conclusions

This study carried out a comparative assessment of the horizontal positional accuracy of Google Earth and Bing imageries of Samaru, Kaduna State, Nigeria, using sixty-three (63) ground survey points as independent reference coordinates. The data reliability evaluation followed the procedure of the National Standard for Spatial Data Accuracy (NSSDA) for horizontal accuracy at the 95% confidence level (FGDC, 1998). The study achieved an overall horizontal positional accuracy of 6.095 m and 6.025 m in terms of RMSE for the Google Earth and Bing imageries, respectively, as the Bing imagery revealed to be more reliable by 0.07 m for determining horizontal positions. The study revealed that there were little or no systematic errors in the Northing direction. The result of the study suggests that it is sufficient for navigation purposes and ground-based measurements that do not require high accuracy. It is, however, suggested that an evaluation of the geometric accuracy of similar or different imageries on the same points as well as in areas of complex topography or terrain should be conducted to determine their geometric quality.

Acknowledgement
The authors acknowledge the Department of Geomatics at Ahmadu Bello University, Zaria, Nigeria for making the Total Station instrument (Leica TCA 1201 M) available at no charge to acquire the ground positional data necessary for the success of this study

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Cite this article as:
Youngu T. T., Aliyu Y. A., Azua S., Bawa S., Bala A. and Hamzat H. D., 2022. Comparative Analysis of the Horizontal Positional Accuracy of Google Earth and Bing Imageries of Samaru, Kaduna State-Nigeria. *Nigerian Journal of Environmental Sciences and Technology*, 6(1), pp. 234-245. https://doi.org/10.36263/nijest.2022.01.0341