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POSITIONAL ACCURACY EVALUATION OF GOOGLE EARTH IN ADDIS ABABA, ETHIOPIA

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ABSTRACT: From the time when it was first launched in 2005, satellite data generated from Google Earth are freely available online. Hence, without being conducting concrete studies about the accuracy of satellite data from Google Earth, Google Earth are chiefly used for different field of studies in different sectors for different purposes in Ethiopia. In this regard, it was planned to conduct this study by establishing the main objective to evaluate the positional accuracy of Google Earth. Hence, in order to address the aforementioned objective, a brief methodology for collecting and analyzing data was performed. The positional accuracy of Google Earth for both horizontal and vertical cases was evaluated. The acquired horizontal RMSE of Google Earth was found fit to produce a class-1 map of having 1:20000 scale as recommended by ASPRS-1990. Unlike for horizontal case, the computed RMSE for vertical positional accuracy of Google Earth was not found fit for preparing class-1 map. However, making correlations between field survey and GE can provide 95% fitness, and also, subtracting the acquired RMSE for the vertical case from the original Google Earth elevation data can provide a 90% fitness for preparing class-1 map as well.

Keywords: Google Earth, RMSE, Field Survey, DGPS, Positional Accuracy.

1. INTRODUCTION

This day Google Earth hosts (< 2.5 meters) imagery from 2000-2008 that distances more than twenty percent of the Earth’s land surface and more than a third of the human population (Potere, 2008). Images at these resolutions allow human observers to freely differentiate between main natural land cover classes and to distinguish components of the human-built environment, including individual houses, industrial facilities, and roads. Some scientists have recently begun using this rapidly escalating cost-free imagery source. GE high-resolution imagery documentation remains a largely untapped resource for the scientific analysis and description of the Earth’s land surface. Launching commercial imaging satellites IKONOS and Quick Bird have generated increased interest in methods that facilitate the efficient extraction of scientifically relevant information from high-resolution imagery (Potere, 2008). Potere

(2008) in work to assess horizontal positional accuracy for the selected average of four points in 109 cities and compare Google Earth accuracy with Landsat image accuracy. The overall accuracy (RMSE) he found of the full sample 436-control points was 39.7m with a range of 0.4 to 171.6 meters. Different accuracy was found in different world locations (Kattan et al., 2016). Mohammed et al (2013) checked horizontal and vertical accuracy in the Khartoum area by comparing Google Earth measured coordinates of points with (GPS) coordinates oversample of 16 checkpoints located in Khartoum State. Root Mean Squared Error (RMSE) was computed for horizontal coordinates and was found to be 1.59m. For elevation measurement, RMSE was computed to be 1.7m.

Farah and Algarni (2014) examined the horizontal and vertical accuracy in Riyadh, King Saud University area by comparing Google Earth imagery estimated coordinates over nine stations measured coordinates by Differential GPS in static mode. The RMSE was computed for horizontal position obtained to be 2.18m and for vertical measurement RMSE was 1.51m. Ahmed and Ayman (2015) tested a part area and landscape of Ain Shams University Campus, Cairo. Their work evaluated the positional accuracy of Google Earth comparing coordinates extracted from Geo-referencing Google Earth imagery used the ERDAS IMAGINE 8.4 software against measured coordinates of points with a Trimble R3, GPS. A horizontal coordinate's deviation was found in the range of 5.89m and 15.68m, with the RMSE was calculated and found to be 10.58 m.

Khalid (2016) was investigated the vertical accuracy of Google Earth for DEM creation in the northern beach of Egypt at three regions namely: Dabaa, El-Alamein, and Mattroch. He compared the estimated elevations of Google Earth over an elevation of 200 control points measured by using GPS. The RMSE of the vertical accuracy of the three regions that he was called: R_1, R_2, and R_3 with an elevation difference of 5, 15, and 25 were computed as 1.85, 3.57and 5.69 respectively. Thus, he was observed that as the elevation difference increases, the accuracy of Google Earth in DEM creation would not be fine.

2. MATERIALS AND METHODS

The research was conducted in Addis Ababa, at Koye Feche area. Koye Feche is located in the southeast direction of Addis Ababa, the capital city of Ethiopia at geographic coordinates of 8^0 54'11" North and 38^0 49'60" East. It is found about 20km far from the center of Addis Ababa.

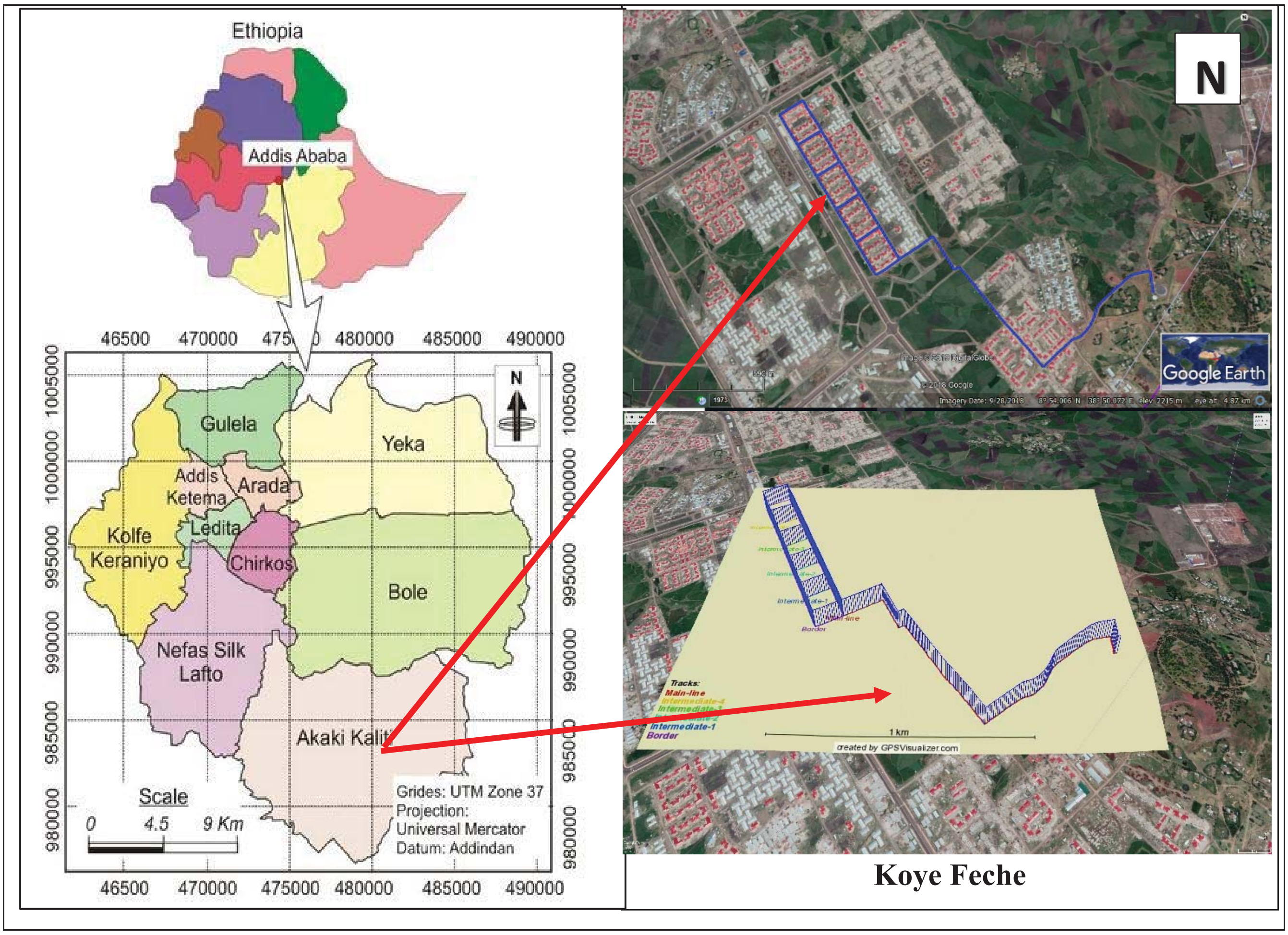

Fig. 2.1. Location map of the study area
(Source: Mesele et al., 2017 and Google Earth, 2019*)*

2.1 Selection processes of sample case study

Before selecting the study area, the sampling process that was made by previously conducted studies, which were related to this research was compiled and seen furtherly. Since the results of previously done studies have shown that there is a significant result difference in different topographical conditions, they were shown that the sample study area selection processes should comprise distinct topographical conditions. Moreover, in order to conduct all round or acceptable studies, the selected sample study area should comprise the most determinant factors and should be representative. The key determinant factors as identified by previously done studies are elevation (steepness and flatness of the area), cloud effects of the satellite images (blurred and clear satellite images) and obstructions like; forests, high rise buildings, etc. Generally, the selected area comprises different terrains conditions found in between 0-75m elevation differences. Therefore, the selected elevation difference is capable to evaluate the performances of using satellite data for engineering projects as a preliminary study.

2.2 Sample sizing and techniques

Samples should be representative in order to powerfully represent the entire data sets. Therefore, for better results, enough number of samples in this study were taken. A hundred Google Earth control points were taken as a sampling point. The Google Earth control points were taken both from hilly and flat areas found in this case study, see figure 2.2 below.

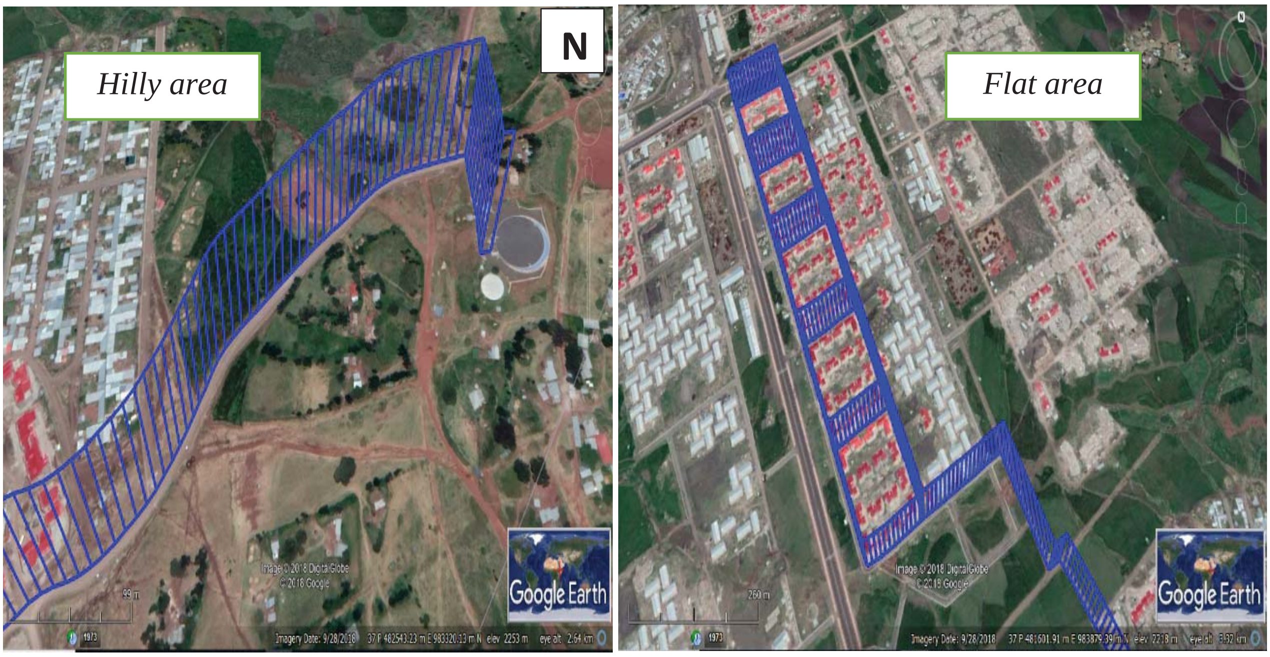

Fig. 2.2. Three-dimensional view of Google Earth control points at the hilly area at roadsides (left) and flat area (right)

2.3 Satellite and field survey data

Satellite data from Google Earth and field survey data in the study were used as an input data for evaluations of positional accuracy of Google Earth As input data are the building blocks engineering projects, an accurate collection and gathering of information are from them were prepared seriously. As when the objective of this research was stood to evaluate the positional accuracy of Google Earth, the way of collecting such data for both cases were different.

In the case of satellite, the input data such as: latitude, longitude, and elevations of points were extracted from google earth software. Whilst, in the case of field survey, conducting Differential global positioning system (DGPS) were collected. Google Earth elevation data that was ultimately used for the comparison purposes with field survey was collected via the following steps.

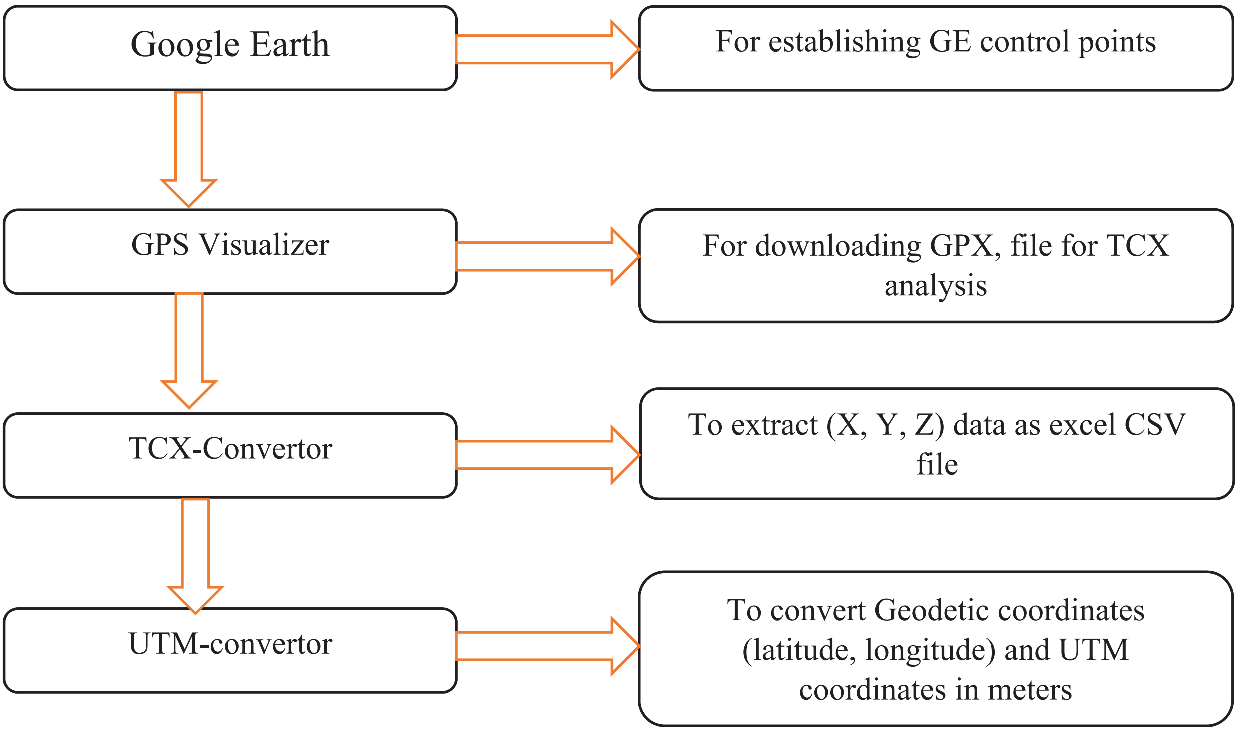

Fig. 2.3. Overview of Google Earth data collection

Since field surveyed coordinate data were used as a reference to evaluate satellite coordinate data, a surveying instrument of having a ±2cm level of accuracy was used. The instrument was a real-time kinematic differential global positioning system (RTK-DGPS), model, SOKKIA SCH250. RTK-DGPS is a satellite navigation technique used to enhance the precision of position data derived from the satellite-based positioning system. This surveying instrument has had a tendency to measure coordinates of points up to 6km radius, once fixed at a certain base station. While performing RTK-DGPS surveying; first, a base station was established over an open area as shown in figure 2.4, to minimize and avoid the obstruction effects it might appear due to the presence of high-rise buildings, trees and other satellite interrupting structures found in the study area.

Second, appropriate instrument setup and adjustment were carried out as shown in figure 2.4, for making sure that the radio connection of base station RTK-DGPS was properly connected via Bluetooth with the other RTK-DGPS (Data-Rover) that was used movably for the measurement processes in conjunction with the data recorder/controller shown in figure 2.4. or making sure that the radio connection of base station RTK-DGPS was properly connected via Bluetooth with the other RTK-DGPS (Data-Rover) that was used movably for the measurement processes in conjunction with the data recorder/controller shown in figure 2.4.

Third, the coordinates of points in the study area were recorded with data recorder/controller starting from the hilly areas up to the flat areas of the study figure 2.4. Eventually, the recorded coordinate data in RTK-DGPS (i.e from Data-Controller) were transferred from data recorder via a memory card to the laptop computer as a comma-separated value (CSV) file format.

Fig. 2.4. RTK-DGPS adjustment at the base station (left) and the adjusted base station Receiver) (right)

Fig. 2.5. Taking the first measurement at the hilly area (left), data controller/recorder (right)

2.4 Positional accuracy assessment

Metrics selection for accuracy assessment needs great attention because the outcomes of the study are dependent on its certainty. In this regard, Morley et al. (2018) were grouped the prominent error metrics as for the accuracy assessments and for biases error. Hence in their study, they were grouped mean squared error (MSE), Root mean squared error (RMSE) and mean absolute error (MAE) for the accuracy assessments. Based on this, since the aim of this study was related to the accuracy assessments, the aforementioned error metrics such as; RMSE and MAE were selected and used for the evaluation purposes. In addition to this, standard deviation and mean error (ME) were also used for comparison purposes.

$$\mathrm{MAExy} = \frac{\sum|(X_a - X_f) + (Y_a - Y_f)|}{n} \tag{2.1}$$

$$\mathrm{MExy} = \frac{\sum(X_a - X_f) + (Y_a - Y_f)}{n} \tag{2.2}$$

$$\sigma xy = \sqrt{\frac{\sum(X_i - \mu)^2}{N}} \tag{2.3}$$

$$\mathrm{RMSE_H} = \sqrt{\frac{\sum(X_a - X_f)^2 + (Y_a - Y_f)^2}{n}} \tag{2.4}$$

$$\mathrm{RMSE_V} = \sqrt{\frac{\sum(Z_a - Z_f)^2}{n}} \tag{2.5}$$

Where, MAExy = Mean absolute error x, y directions,
MExy = Mean error in x, y directions
$RMSE_H$ = Horizontal root mean squared error,
RMSEy = Vertical root mean squared error
σ = Standard deviation,
X_i = Observed data in i's direction,
μ = Mean of observed data
X_a = Actual data in X-direction,
X_f = Forecast data in X-direction
Ya = Actual data in Y-direction,
Y_f = Forecast data in Y-direction
Za = Actual data in Z direction
Zf = Forecast data in Z direction,
n = Number of observations& N = n-1

3. RESULTS AND DISCUSSIONS

The obtained root mean squared error (RMSE) for a hundred Google Earth control points in this study was 4.58m with an error range of [0.31-12.31] m as indicated in figure 3.1. This shows that, while comparing the values with the findings of Potere (2008), in his study for worldwide level positional accuracy assessment of Google Earth for Africa case scenario, significant differences were found. This remarkable difference might result due to the enhancement of Google Earth imageries; meanwhile, the compared results had had 11 years' time variance. Due to this time variance, tremendous enhancements in satellite imageries might be made and Pulighe et al. (2016) were verified and tested this further enhancement in satellite imageries within different time scenarios, in their study at Rome city.

For instance in Africa case, as done by Potere (2008), the overall horizontal positional RMSE was 46.2m, and the overall horizontal positional RMSE of this study was 4.58m, hence, 41.62m differences were observed as compared to the values obtained in this study. At the global level, as done by Potere in (2008), the acquired horizontal positional accuracies for different continents are significantly varied with the values obtained in this study both in RMSE as well as in minimum and maximum error intervals as indicated in figure 3.1. The discrepancies in RMSE while benchmarking the results of the horizontal positional RMSE of this study for comparing with USA, Europe, Asia, and World were; 18.02m, 21.12m, 37.72m, and 35.12m respectively.

The acquired horizontal positional accuracy in this study, that was 4.58m in RMSE, which was fall in the ranges of [0.0125 – 5.00] m, can produce class-1 map of having 1:20000 map scale according to ASPRS (1990), about accuracy standards of large-scale maps. However, in the vertical positional accuracy case, the acquired accuracy was 15.91m in RMSE see figure 3.2, which exceeds too much the ASPRS (1990) standards for the vertical case, that was [0.5-2] m; then it cannot produce the required map scale in Addis Ababa. Hence, for the horizontal positional accuracy case, it is possible to use Google Earth in Addis Ababa for practical purposes as recommended by (ASPRS, 1990). In addition, significant error ranges were also observed as indicated in figure 3.1.

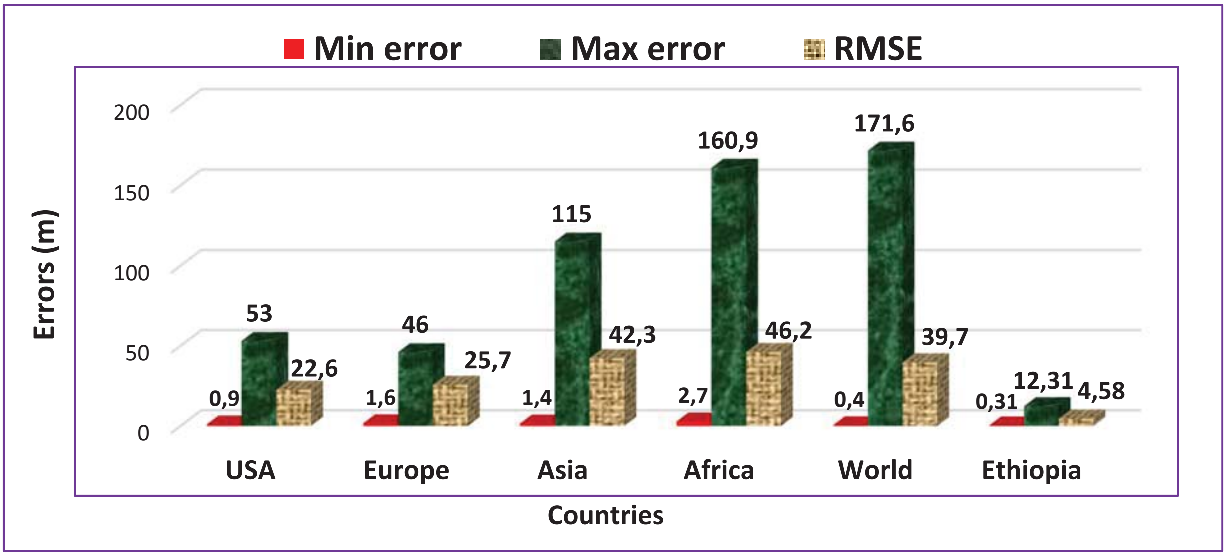

Fig. 3.1. Comparisons of horizontal positional RMSE of Google Earth as conducted by Potere in (2008) at the global level with the result of this study (Ethiopia….Addis Ababa)

In the meantime, the comparisons made in the above figure 3.1 were the study conducted by Potere in (2008) at global perspective with this study. It was an indication of how fast satellite imageries are enhancing from time to time. Then for better comparison, the recent and latest studies done by distinct researchers at city and country level were also compared accordingly. The studies, in Khartoum city by Mohammed et al (2013), in Riyadh city by Farah and Algarni (2014) and in Cairo city by Ahmed and Ayman (2015) were compared with this study. Hence, among the compared four cities as indicated in figure 3.2, better accuracy in RMSE for both horizontal and vertical positional accuracies of Khartoum city was observed.

Among the stated cities in figure 3.2, only Khartoum city can fit or fulfill both the vertical and horizontal positional accuracy standards by (ASPRS, 1990) for producing a class-1 map of having 1:5000-1:10000 map scale. This might be due to the flat topography of Khartoum city as compared to Addis Ababa, Cairo, and Riyadh. The topography is one of the major factors for the accuracy of satellite images (Google Earth). Khalid (2016) proved this, in his study of three places in the northern beach of Egypt of having different elevation differences or profiles.

Moreover, Khalid (2016) was concluded that, as the elevation difference increases, the positional accuracy of Google Earth would be decreased. In line with Khalid's conclusion, since the topography or altitude of Addis Ababa city is too high as compared to the rest cities as indicated in figure 3.2, a higher vertical positional RMSE of Addis Ababa city was observed. While in Riyadh city, a better horizontal and vertical positional RMSE was also observed. The vertical positional RMSE of Riyadh city is better than all the rest-compared cities. In case of Cairo city, even if the positional RMSE of 10.58m that was better than the vertical RMSE of Addis Ababa city that was 15.91m, it cannot produce a large map scale as recommended by (ASPRS, 1990).

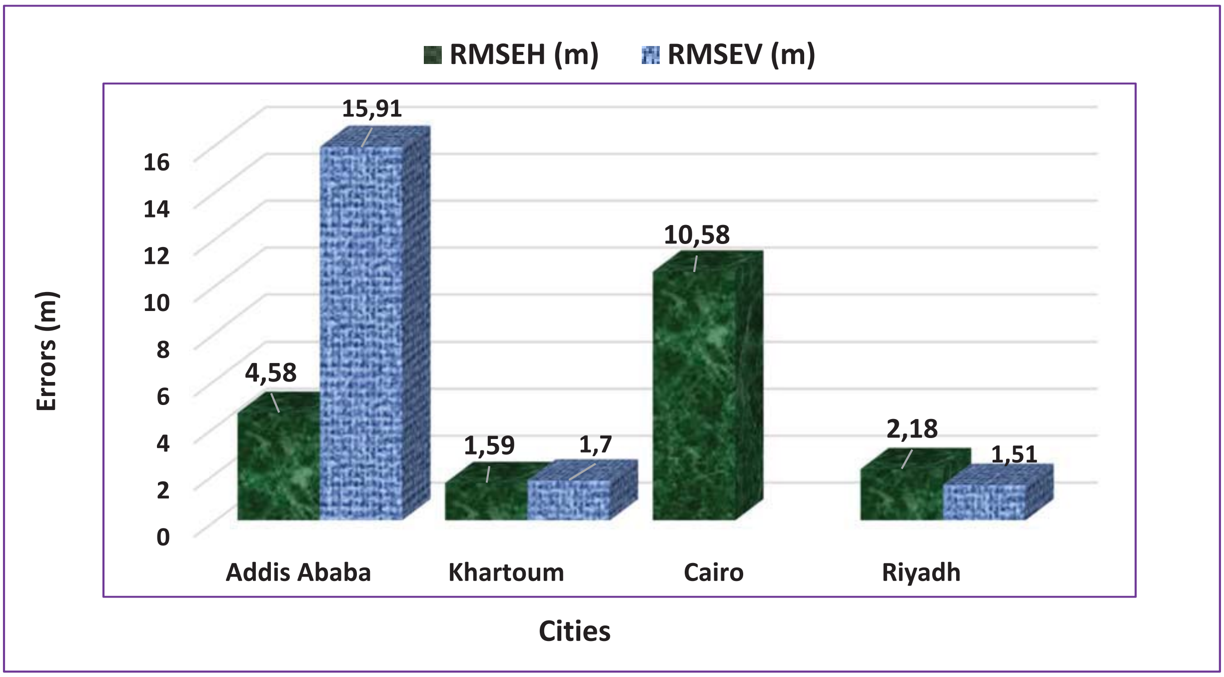

Fig. 3.2. Comparisons for horizontal and vertical positional root mean squared errors of Google Earth of four cities

Generally, the computed error metrics in this study for the hundred Google Earth control points are indicated in Table 3.1.

Table 3.1. Error matrices of Google Earth for the adopted hundred control points

Positional directions	**Error metric's**				
	Root mean squared error (RMSE) (m)	Mean absolute error (MAE) (m)	Mean error ME (m)	Standard deviation (σ) (m)	Error range (m)
X	4.62	3.72	0.12	2.76	[0.37-14.37]
Y	4.54	3.70	0.02	2.65	[0.24-10.24]
Z	15.91	15.86	-15.56	1.17	[13.64-18.59]

Figure 3.3 has displayed that, the extracted elevations for a hundred sampled points of Google Earth was higher than the elevations measured by using a differential global positioning system (DGPS). As it can be shown from the elevation profiles of both Google earth as well as DGPS in figure 3.3, nearly a constant increment in elevations was observed. In addition, this could be portrayed as the emerging's of systematic error in between them. Hence, in this case, knowing error discrepancy with the computed RMSE is very indispensable in order to adjust the deviations.

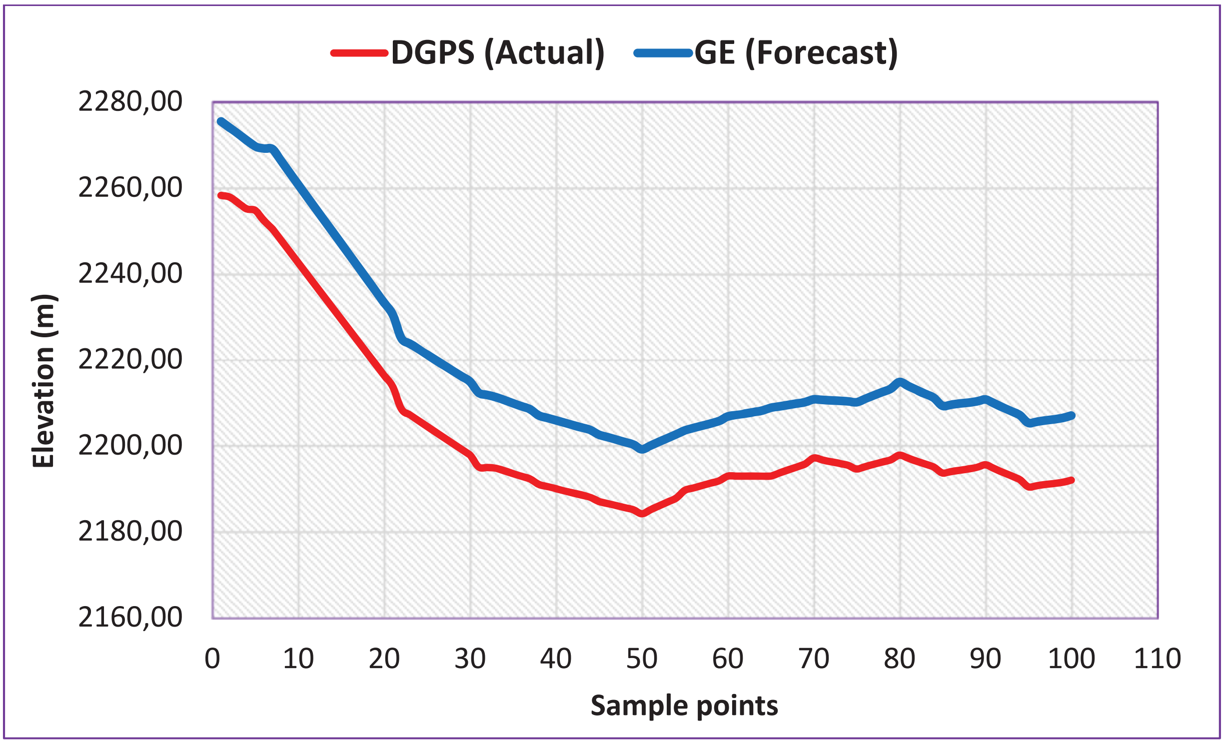

Fig. 3.3. Elevation profiles of DGPS versus Google Earth for a hundred sample points

The maximum and minimum error ranges of vertical accuracy in Addis Ababa city were in the range of [13.64 – 18.59] m. Moreover, this error range depicts that there is an error difference of 4.95 m in between the maximum and minimum error intervals. This error difference looks not as such significant. Consequently, error discrepancy test was performed to quantify how much are the distinctions in between the computed vertical positional RMSE and the computed error discrepancy from the RMSE. Then, a maximum and minimum elevation discrepancy that were 2.68m and 0.00 m respectively was observed as indicated in figure 3.4 below. This portrays that Google Earth elevations can be adjusted by subtracting the computed error discrepancies.

The maximum error discrepancy that was 2.68 m was observed in the hilly area, and the minimum error discrepancy that was 0.00m was observed in the flat area. Therefore, it is possible to enhance the acquired vertical positional RMSE in Addis Ababa city by subtracting the computed RMSE from the original elevation data from Google Earth. In order to use elevations from Google Earth in Addis Ababa for the practical purposes, it is advisable to subtract the acquired RMSE and taking field measurements at hilly areas with high-performance surveying equipment. The enhanced maximum error discrepancy that was 2.68 m was a slight far from ASPRS (1990), standards for the vertical positional RMSE that were found in between [0.50 -2.00] m. Figure 3.4 shows how much error ranges can possibly be reduced while subtracting the computed vertical positional RMSE, that were found from the range [13.64 – 18.59] m to [0.00 – 2.68] m.

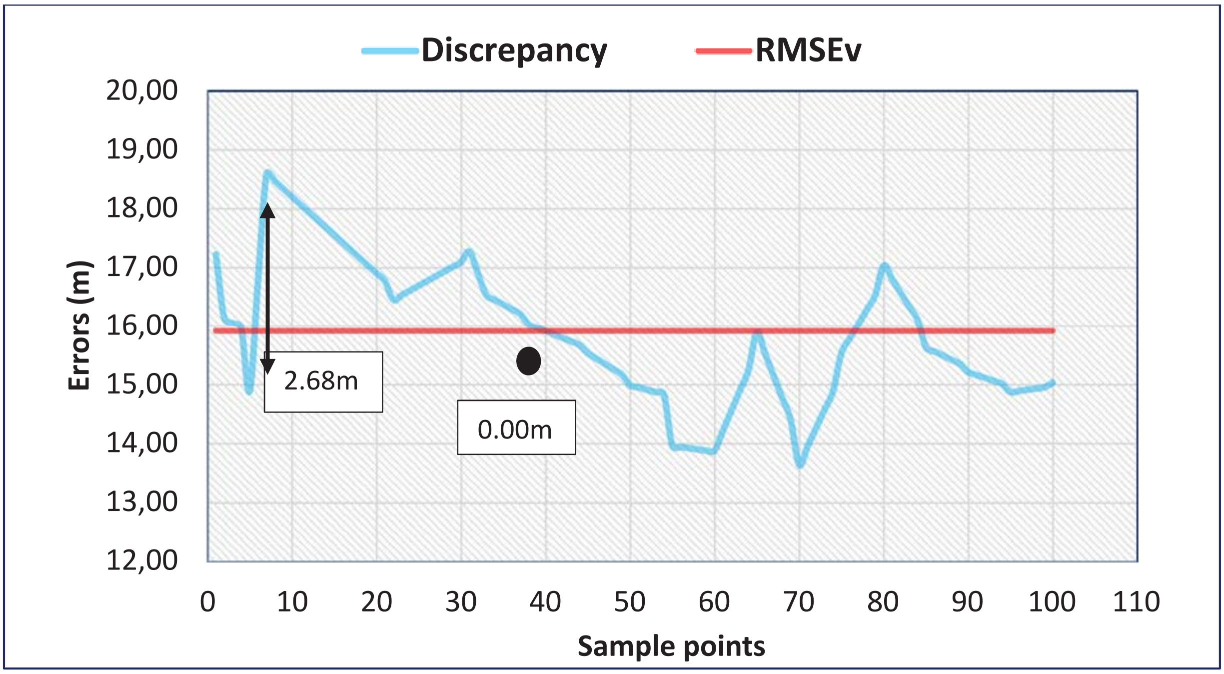

Fig. 3.4. Error discrepancy of Google Earth in reference with the computed vertical RMSE

After adjustments, 90% of Google Earth elevation data were fitted with elevations of the differential Global Positioning System (DGPS) and the rest 10% were not fitted while it was compared with ASPRS (1990) standards for vertical accuracy assessments, which was a maximum of [0.50-2.00] m for producing class-1 large scale map, see figure 3.5.

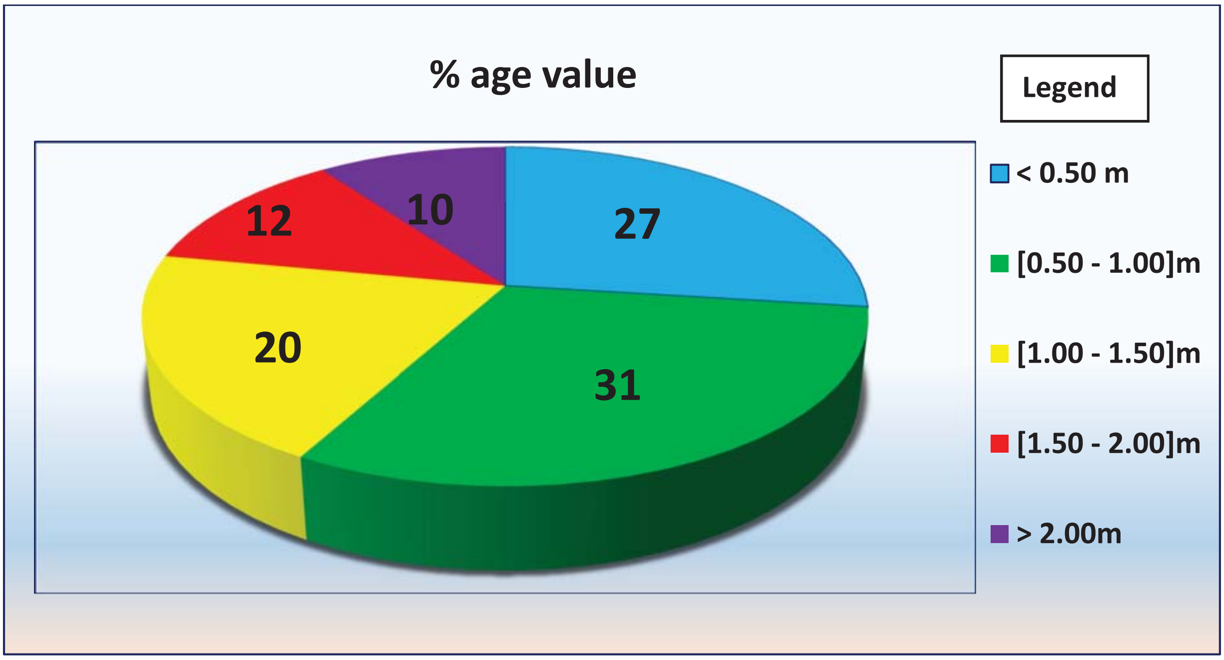

Fig. 3.5. Percentage distributions of error discrepancy of Google Earth after adjustments

As shown in figure 3.6, the corrected Google Earth elevation has fitted better with the actual reference (DGPS elevations) while subtracting error discrepancies indicated in the above figure 3.4. The fitted elevation profiles of Google Earth with the reference DGPS is shown in figure 3.6.

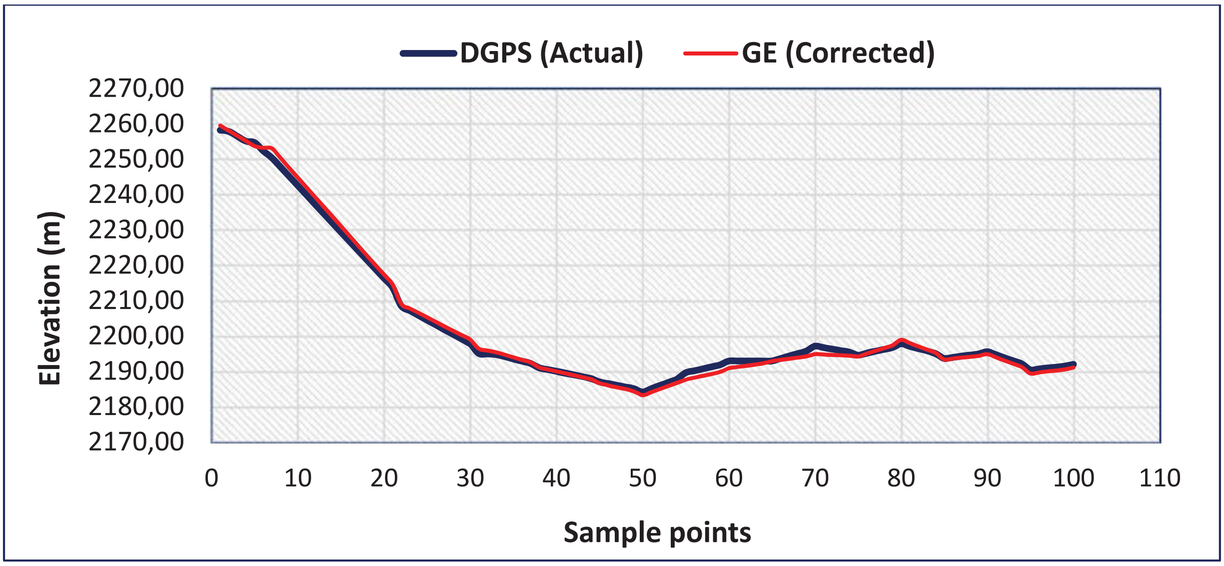

Fig. 3.6. Elevation profiles of DGPS versus Google Earth after making a correctional adjustment

Beyond subtracting the acquired RMSE from Google Earth elevation data, applying correlation coefficient between field survey and Google Earth elevation data can provide 95% fitness. Here in the consecutive figure 3.7 and 3.8 below, the correlations and the fitness tests in between Google Earth and field survey data are indicated.

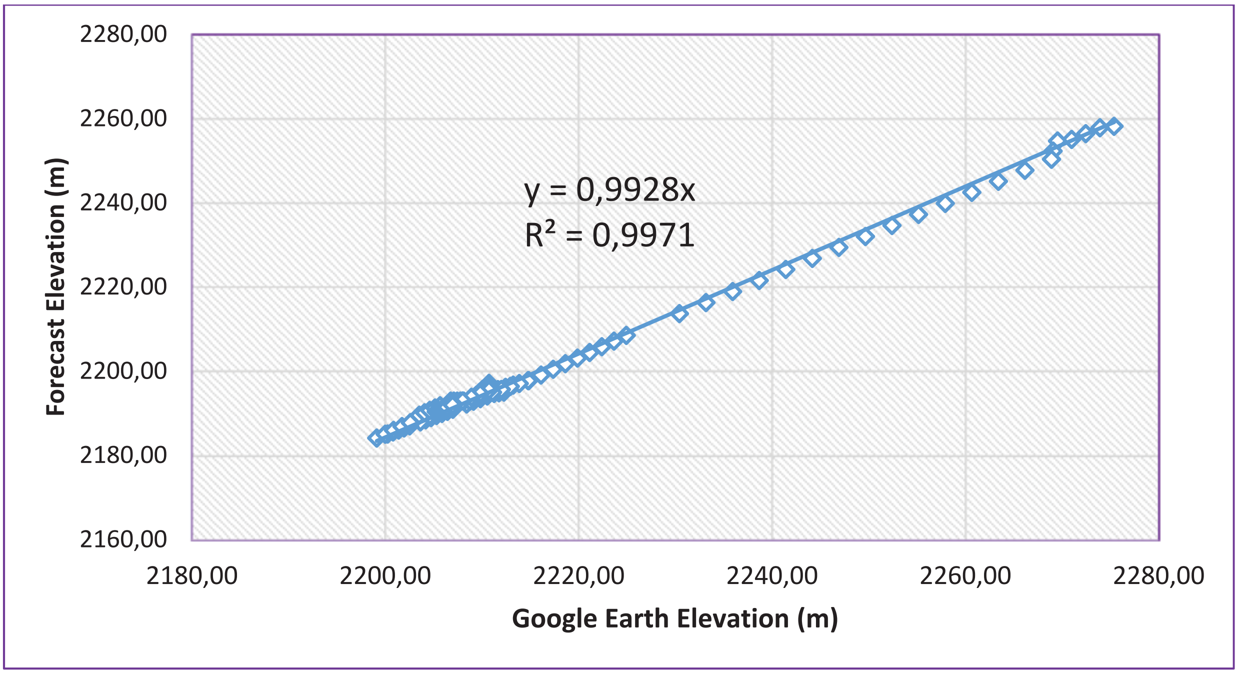

Fig. 3.7. The correlation coefficient between Google Earth and actual field survey elevation

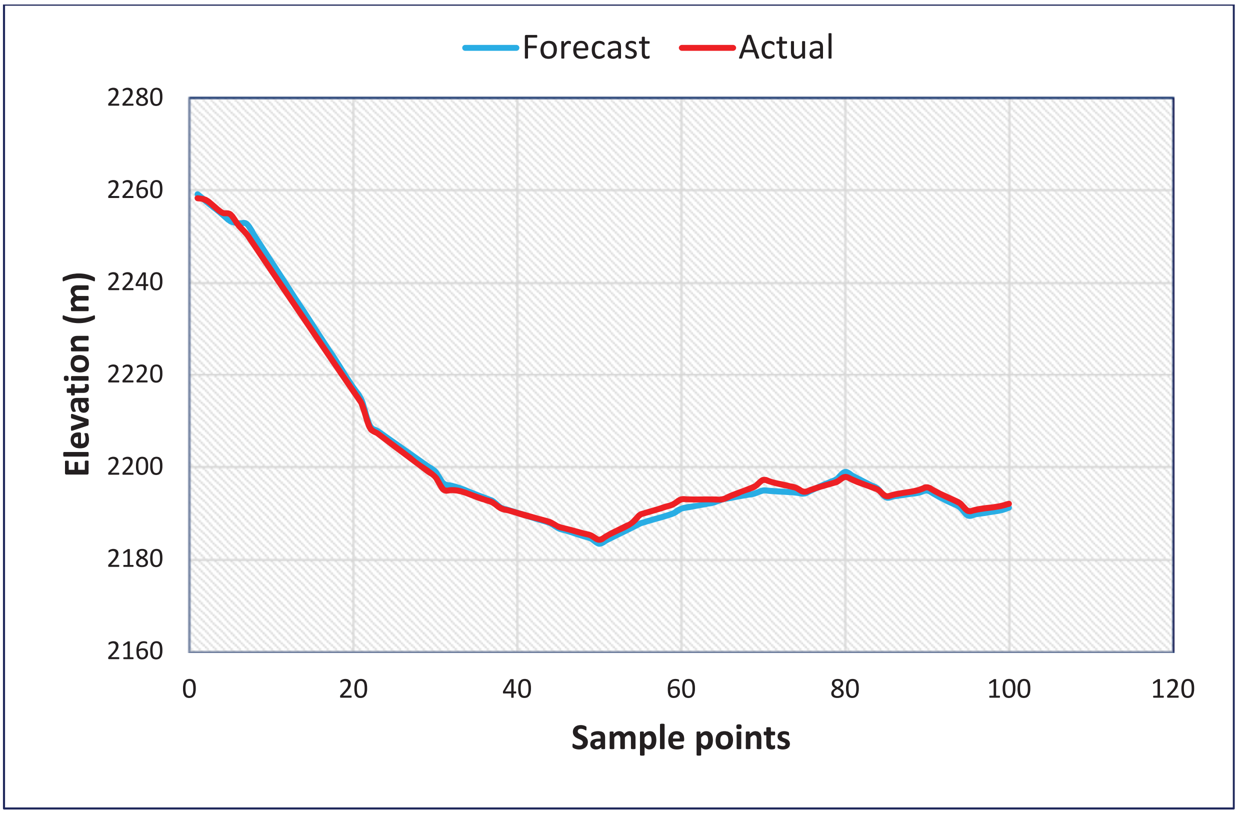

Fig. 3.8. Elevation profiles of DGPS versus Google Earth after making a correctional adjustment based on the correlation coefficient.

4. CONCLUSIONS

This study was addressed the aforementioned objective that was Evaluation of positional accuracy of Google Earth based on a clearly stated methodology. The positional accuracy of GE for both horizontal and vertical cases was evaluated. The acquired horizontal RMSE of GE was found fit to produce a class-1 map of having 1:20000 scale as recommended by (ASPRS, 1990). Unlike for horizontal case, the computed RMSE for vertical positional accuracy of GE was not found fit for preparing class-1 map. However, making correlations between field survey and GE can provide 95% fitness and also, subtracting the acquired RMSE for the vertical case from the original GE elevation data can provide a 90% fitness for preparing class-1 map. Finally, it is recommended to conduct a study on this thematic area focusing on the positional accuracy in forest land use cases.

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