Assessment of Positional Accuracy of Google Earth Imagery: A Case of Adama city

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A Thesis Submitted to Department of Geomatics Engineering

School of Civil Engineering and Architecture

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Adama, Ethiopia

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DECLARATION

I declare that this Master Thesis entitled ‘‘Assessment of Positional Accuracy of Google Earth Imagery” is my own work and has not been submitted to any university for similar purpose. The references used in this thesis are duly recognized by proper citations.

Sintayehu Tamiru	________________	________________
Name of student	Signature	Date

RECOMMENDATION

I, the major advisor/supervisor of this Master Thesis, hereby certify that I have closely advised/supervised the student while developing this proposal and read the draft thesis proposal entitled ‘‘Assessment of Positional Accuracy of Google Earth Imagery “prepared under my guidance by **Sintayehu Tamiru.** Therefore, I recommend the submission of the thesis to the department for further review and evaluation.

Getachew Birehanemeskel (Ph.D.)	____________________	____________________
Major Advisor/Supervisor	Signature	Date
______________________________	____________________	____________________
Co-advisor/Co-supervisor	Signature	Date

APPROVAL SHEET

I, the advisor of this thesis entitled, Assessment of Positional Accuracy of Google Earth Imagery: A Case of Adama City and developed by Sintayehu Tamiru Tadese, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Getachew Birehanemeskel (Ph.D.)	________________	________________
Major Advisor/Supervisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Sintayehu Tamiru Tadese have read and evaluated the thesis entitled ― "Assessment of Positional Accuracy of Google Earth Imagery: A Case of Adama City: A Case of Adama City" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geoinformatics Engineering.

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Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

Department Head	Signature	Date
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ASCE:	American Society of Civil Engineering
ASPRS:	American Society of Photogrammetry and Remote Sensing
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTU:	Adama Science and Technology University
BM	Bench Mark
CCS:	Cartesian coordinate system
CEP:	Circular Error Probable
DEM:	Digital Elevation Model
DTM:	Digital Terrain Model
E:	Easting
EMA	Ethiopian Map Agency
EMAS:	Engineering Map Accuracy Standard
GCP:	Ground Control Point
GDB:	Geodetic Data Base
GE:	Google Earth
GECP:	Google Earth Control Point
GIS:	Geographical Information System
GPS:	Global Position System
HHGPS:	Hand Held Global Position System
IGSS	Institute of Geo-Spatial Science
KML:	Keyhole Markup Language
MAD:	Median Absolute Deviation
MSL:	Mean Sea Level
N:	North
NGA	National Geodetic Agency
NGO:	Non-Governmental Organization
NGS:	National Geodetic System
NSSDA:	National Standard for Spatial Data Accuracy
OGC:	Open Geospatial Consortium
PAH:	Positional Accuracy Handbook
RMSE:	Root Mean Square Error

RTK-DGPS:	Real Time Kinematic-Differential Global Position System
SD:	Standard Deviation
SEM:	Standard Error of the Mean
SEP:	Spherical Error Probable
SRTM	Shuttle Radiometric Thermal Mapper
TS:	Total Station
UTM:	Universal Transvers Mercator
UPS:	Universal Polar Stereographic
WCB:	Whole Circle Bearing
WGS:	World Geodetic System

ABSTRACT

Google Earth (GE) is the most popular virtual globe in use today. Given its popularity and usefulness, most users do not pay close attention to the positional accuracy of the imagery, and there is limited information on the subject. This study therefore evaluates the horizontal accuracy of historical Google Earth imagery at two epochs between year 2013 and 2023, and the vertical accuracy of its elevation data within Adama city. The horizontal accuracies of the images were evaluated by comparison with Global Position System coordinate which measured by former name of Ethiopian Mapping Agency (currently known as Institute of Geo-Spatial Science) and the vertical accuracy was also assessed by comparison with a network of 142 Ground Control Points. To mark elevation data of Google Earth, first Ground Control Points were converted into Keyhole Markup Language data format, then open it Google Earth pro, mark the perspective points of Google Earth and save folder of GE marked data. After that the data was converted into feature using GIS software. To generate Z value of Google Earth Advanced Land Observation Satellite (ALOS) Digital Elevation Model was downloaded and imported into GIS software and Z was generated. The positional accuracy for both horizontal and vertical was performed. The latest or recent Google Earth imagery (year 2023) was the most accurate than Google Earth imagery of 2023. The horizontal Root Mean Square Error of Google Earth imagery of 2013 was estimated 5.98846m and 3.9154m in 2023. Vertical positional accuracy of Google Earth was estimated at a value of 15.97m. The estimated Root Mean Square Error of Google Earth was found fit to produce a class-1 map of having scale of 1:20000 as recommended by ASPRS-1990. Also the positional accuracy of Google Earth was seen improving.

Keywords: RMSE, Positional Accuracy, Positional Accuracy Standard, (ALOS) World 3D - 30m (AW3D30) DEM, GPS, Google Earth.

CHAPTER I: INTRODUCTION

1.1 Background of the study

Google Earth (GE) is one of the most influential and popular virtual globe tools. It was launched in 2005 by Google (Mohammed, Ghazi, & Mustafa, 2013). It aimed to map the Earth through high resolution satellite and aerial images. Google earth has also the ability to show 3D buildings and structures such as bridges for the main and important cities and places around the world. The images displayed in Google Earth are varying based on specific area. It is ranging from Quickbird, IKONOS, and GeoEye-1 images for urban areas to SPOT5 and Landsat images for deserts and continental scale view (Google, 2007). Google Earth uses the Keyhole Markup Language (KML) format to describe and display features such as points, lines, polygons and images.

Google Earth is a useful interactive mapping tool that allows users to control oblique perspective views of the earth. This perspective view makes it possible to blend three-dimensional features of the earth's surface with traditional two dimensional map spaces. The Google Earth user can view a mountain range obliquely by controlling the angle of view. It is also possible to input a building as a 3-D object. This allows users to view a three-dimensional cityscape.

Unfortunately, given the popularity of GE, users tend to assume that it is an accurate source of information and also tend not to question its credibility (FLanagin & Metzger, 2008). Also, the practice of GE of reporting coordinates with a precision that does not match its accuracy misleads users to believe that it is an accurate source of information (Goodchild, et al., 2012). Moreover, (Benker, Langford, & Pavlis, 2011) note that Google representatives state that the coordinates provided by Google are approximations only and that, therefore, Google makes no claims as to the accuracy of their geographic information products (Google, 2008, 2009). However, in 2008, Google initiated a project called "Ground Truth" in order to increase the accuracy of their geographic products by means of acquiring data from authoritative sources (Google, 2012) such as INEGI (the Mexican National Institute for Geography and Statistics) and NGA (the USA National Geospatial-Intelligence Agency).

Every position on GE images can be described by the values of latitude, longitude and altitude. The horizontal geographic coordinates are measured from WGS-84 reference system (World Geodetic System which was devised in 1984), while the vertical component is defined by WGS-84 EGM96 Geoid vertical datum (Nagi., 2013). This is the main strength of using GE data because users can store, share and display geospatial data on one spherical Earth model rather than multisource coordinate systems. Free accessible of various types of remotely sensed images in GE are another significant merit. Although these positive aspects, however, the inconsistency of the images quality can be considered the main limitations of GE data. High resolutions images cover only 20-30% of the whole world (Le Yu and Peng Gong, 2012). This may lead to poor horizontal positional accuracy of GE imagery. Hence, this research has been undertaken in order to improve the quality of GE data.

In addition, its derived coordinates usually being reported with a precision that does not match its accuracy due to number of reasons like security threats, instrumental errors etc. Sometime these errors are intently introduced for security reasons, which misleads users to believe that it is an accurate source of information. Therefore, in order to understand and reduce the uncertainties associated with the use of Google Earth in different applications, accuracy assessments of its corresponding imagery are required. As geospatial researcher, GE software is applicable in most of geospatial projects or researches. But most of this practice didn't consider the positional errors of this software. This is the reason that motivated me to do this study. In this study, I want to remind for the reader of this thesis I will not going to assess the error of GE software rather than my study only focus on assessing amounts of errors of GE on the study area when compared to GPS data.

1.2 Statement of the problem

The positional accuracy of cartographic products has always been of great importance. It is, together with logical consistency, the quality element of geographic information most extensively used by the national mapping agencies NMAs, and also the more commonly evaluated quality element option (Jakobsson, 2002). Positional accuracy is a matter of renewed interest because of the capabilities offered by the global positioning system GPS and the need of a greater spatial interoperability for supporting the spatial data infrastructures. A different positional behavior of geographic data sets means the existence of an inter-product positional distortion and a barrier to interoperation (Church, 1998). This barrier is not only for the positional and geometric aspects, but also for thematic ones which are greatly affected by position (Carmel, 2006). For these reasons many NMAs are currently involved in the development of positional accuracy improvement programs (European Spatial Data Research (EuroSDR)., 2004). Positional accuracy has always been considered a defining and essential element of the quality of any cartographic product (Ariza-López, 2002) as it affects factors such as geometry, topology, and thematic quality, and is directly related to the interoperability of spatial data.

Despite its numerous advantages, the positional accuracies of GE imagery are not officially published because of GE uses different combinations remote sensing data for different area. Even though they are not expected to make damage in many projects or studies, lack of this information can potentially make problem in the tasks requiring a higher positional accuracy, such as map making, decision making, change detection analysis etc. This issue is an important challenge against using GE in precise and sensitive applications. Therefore, it is necessary to assess the positional accuracies of GE imagery before using it in such applications.

Consequently, a series of accuracy assessments of GE's imagery have been undertaken by different researchers. (Potere, 2008), evaluated the horizontal positional accuracy of GE's imagery using control points extracted from the Landsat GeoCover dataset and estimated a global horizontal root mean squared error (RMSE) of 39.7 m. However, the horizontal accuracy of Landsat GeoCover, about 50 m RMSE (Tucker, Grant, & Dykstra, 2004), is larger than the accuracy estimated for GE. Therefore, the results should be interpreted conservatively due to the uncertainty introduced by the dataset used as reference (Potere, 2008). In a similar global study, (Becek & Ibrahim, 2011), estimated GE's global horizontal mean error in 113 m, with errors in the range from 10 to 1,500 m, using as reference runways compiled from multiples sources. Unfortunately, since (Becek & Ibrahim, 2011) do not state the estimated accuracy of the dataset they used in their study, their results should also be handled with caution.

Regarding regional studies, (Mulu, 2019), done horizontal and vertical positional accuracy assessment of GE by using a surveying instrument of having a ± 2 cm level of accuracy RTK-DGPS, model, SOKKIA SCH250. Their study area coverage was Koyefeche, sub city of Addis Ababa and found that GE's imagery has horizontal RMSE 4.58m and vertical RMSE was 15.91m. However, their GE positional accuracy assessment was only focused one study period of GE imagery data and limited study area coverage. As another researcher confirmed that the spatial resolution and positional accuracy of GE improved from time to time, assessment of historical GE and current GE imagery is important. Moreover, (Khalid, 2016) was concluded that, as the elevation difference increases, the positional accuracy of GE would be decreased. Based on this conclusion the elevation difference between Addis Ababa and Adama city is very high, so on this study area (Adama city) positional accuracy assessment is important. Also the input data they used was not georeferenced scene, they take as it is GE imagery.

Therefore, in this paper positional accuracy of GE imagery of two selected years (2013 and 2023) addressed to understand the extent positional accuracy improvement between time difference by means of using accurate control points, field observation data by using Total station and photogrammetric measurements as reference data and addressing some of issues identified in the previous studies.

1.3 Objective of the Study

1.3.1 General Objective

The main objective of this research is to evaluate both horizontal and vertical positional accuracy of GE Imagery of between the years 2013 and 2023 in study area of Adama city-in Ethiopia by using DGPS points, Total Station measured coordinates and GE Imagery.

1.3.2 Specific Objectives

- To determine coordinate difference between the GPS, TS data and GE data for each study periods
- To determine horizontal errors or shifts in the GE images in years 2013 and 2023
- To calculate the positional accuracy of these GE's imageries based on GPS data using statistical measures
- To evaluate GE accuracy in terms of both GPS and Total Station points and compare with to ASPSR standards for application

1.3 Research Questions

Based on the above stated specific objectives this research aims to answer the following questions:

1) Is GE positional accuracy increase or decrease from the year 2013 to 2023?
2) What is the level of difference or discrepancy between GE Imagery of both years and GPS and Total Station points?
3) On which year of highest horizontal error or shift was recorded?
4) Is GE data is recommendable for application purpose when compared to ASPSR standards for the study area?

1.4 Significance of the Study

The relevance of this research was mainly evaluating horizontal and vertical positional accuracy of GE based on GCP collected through ground survey. Coordinates from Adama city municipal, previous research documents, coordinates measured by Total Station and GE imagery will be used as data source. The research will also serve as an input to the next researchers, government bodies, Engineers, NGOs and other concerned bodies. The study will provide information on the quality of currently used GE imagery data for different purpose.

1.5 Scope of the Study

In this technology world geospatial technology data is a back bone of development for any country. Today, most of developed countries use accurate geospatial data by using modern technologies satellites which have best spatial resolution. As those countries uses their own different kinds of high cost satellites, the acquired data have high positional accuracy and highly expensive. To access such types of data for developing country researchers are impossible. However, GE is a source of geospatial data for different application of developing countries; because this source of data is freely accessible. The data accessed from GE have some positional errors. Also this technology uses different imagery for different continents. The study was mainly focus on assessing horizontal and vertical positional accuracy of GE historical imagery from the years of 2013 to 2023 of Adama city to estimate that the extent of errors and to inform that types of maps that we can produce from GE imagery. The estimated positional errors was quantified and based on this quantity purpose or application we can use this geospatial technology was suggested for study area. This study will be conducted in Adama city, Ethiopia. The findings of this study will be applicable only for Adama city.

1.7 Limitation of the Study

This research was faced the following limitations: Challenges in obtaining previously recorded secondary data from the town's municipality, destruction of monuments of GCPs, difficulty of field data measurement because of high accuracy GPS is difficult to access, and resolution of GE imagery. In addition to this there is no Empirical study on positional accuracy assessment of for study area (published).

1.8 Organization of the Study

This study has reported within five chapter of organization. The first chapter consists of introduction about GE data and positional accuracy of it, statement of the problem, objective of the study, scope of this study and research questions. The second chapter aims to present literature reviews which include theory about positional accuracy frame works, previous studies methodology and results and research gaps. The third chapter contains about research design and methods. The fourth chapter emphasizes data analysis and result. Chapter five aims to present conclusion and recommendation.

CHAPTER II: LITERATURE REVIEW

2.1 Introduction

As the study will focus on assessment of horizontal positional accuracy of GE of Adama city, in this section about positional assessment techniques and geospatial data accuracy standards are explained. Also conceptual terms which related to positional accuracy assessments are discussed. At the end of this chapter, summary of related studies are investigated and will provide justification to (why) of the current study.

2.2 Positional accuracy of spatial data

The quality of spatial data products has to be defined within the appropriate specification framework (ISO, 2007). The production processes should be properly designed and managed so that the intended quality is assured during the production process, and thus attained in the product. Quality assessments are carried out to confirm such quality, which should be based on standardized and well-defined methods. The results of these assessments should be used by producers to understand, improve, and manage their production processes. These results should also be published as metadata for users to be aware of the quality of the products they choose to use. This represents a very broad general quality framework, and this guide only addresses one of the indicated stages, namely quality assessment, specifically positional accuracy assessment.

In a geographic data base GDB the position of a real world entity is described with values in an appropriate coordinate system. Positional accuracy represents the nearness of those values to the entity's "true" position in that system. The positional accuracy requirements for a GDB are directly related to its intended uses. Positional accuracy is determined by means of a statistical evaluation of random and systematic errors (DOD 1990) and specified by means of the root-mean-square error RMSE or by the mean value of errors and their standard deviation. Comparison with an independent source of higher accuracy is the preferred method for assessing positional accuracy (American National Standards Institute (ANSI), 1998).

Using various statistical methods, it can be created many different position accuracy measures. The position is fundamentally three dimensional, but not everyone is interested in obtaining the three dimensional positional accuracy. One user might care about horizontal accuracy, another might want vertical. Thus, we must consider different 1-D, 2-D or 3-D accuracy measures (statistics). Statistics can have varying confidence levels and each of them has its certain importance for particular applications. Each of those measures provides an indication of the spread or dispersion of the set of estimates about their mean or expected value, reflecting the random error in the repeated measurements, so, in fact, they provide an indication of precision or repeatability.

The most commonly used linear measures (1-D) are 1-σ standard deviation (68.27% probability) and 95% Probability/Confidence (95% probability), typical used for expressing the precision of vertical component of position. In 2-D case (horizontal components of position), commonly used measures are: 1-σ Standard Error Circle (39% probability), Circular Error Probable (CEP) (50% probability), 95% 2-D Positional Confidence Circle (95% probability), 2-Dev. Root Mean Square (2DRMS) (95 – 98% probability). In 3-D case, those measures are: 1-σ Spherical Standard Error (19.9% probability), Spherical Error Probable (SEP) (50% probability), 95% 3-D Confidence Spheroid (95% probability) and many others (Diggelen, 1998). GPS positional accuracies are normally estimate and report using root mean square (RMS) error statistic. The probability associated with RMS depends on whether one is using RMS in one, two, or three dimensions.

2.2.1 Geographical Information System (GIS)

2.3. Measure of central tendency

Measures of central tendency are computed statistical quantities that give an indication of the value within a data set that tends to exist at the center. The arithmetic mean, the median, and the mode are three such measures. They are described as follows:

- **Arithmetic mean.** For a set of n observations, y1, y2. . . yn, this is the average of the observations. Its value, is computed from the equation

$$\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n} \quad \ldots\ldots(2.1)$$

Typically, the symbol is used to represent a sample's arithmetic mean *y* and the symbol is used to represent the population mean. Otherwise, the same equation applies.

- **True value, μ:** a quantity's theoretically correct or exact value.
- **Error, ε:** the difference between a measured quantity and its true value. The true value is simply the population's arithmetic mean.

$$\varepsilon_i = y_i - \mu \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.2)$$

Where y_i, is the individual observation associated with ε_i and μ is the true value for the quantity.

- **Most probable value, y:** that value for a measured quantity which, based on the observations, has the highest probability of occurrence. It is derived from a sample set of data rather than the population and is simply the mean if the repeated measurements have the same precision.
- **Residual, v:** The difference between any individual measured quantity and the most probable value for that quantity. Residuals are the values that are used in adjustment computations since most probable values can be determined. The term error is frequently used when residual is meant, and although they are very similar and behave in the same manner, there is this theoretical distinction. The mathematical expression for a residual is:

$$v_i = y - y_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.3)$$

Where v_i i is the residual in the i^{th} observation, y_i, and y is the most y probable value for the unknown.

- Variance, σ^2 : a value by which the precision for a set of data is given. Population variance applies to a data set consisting of an entire population. It is the mean of the squares of the errors and is given by

$$\sigma^2 = \frac{\sum_{i=1}^{n} \varepsilon_i^2}{n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.4)$$

Sample variance applies to a sample set of data. It is an unbiased estimate for the population variance given in Equation (2.4) and is calculated as

$$S^2 = \frac{\sum_{i=1}^{n} v_i^2}{n-1} \quad \ldots\ldots (2.5)$$

- **Standard error, $\boldsymbol{\sigma}$:** the square root of the population variance. From Equation (2.4) and this definition, the following equation is written for the standard error:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} \varepsilon_i^2}{n}} \quad \ldots\ldots (2.6)$$

Where n is the number of observations and $\sum_{i=1}^{n} \varepsilon_i^2$ is the sum of the squares of the errors. Note that both the population variance, σ^2 and the standard error, σ , are indeterminate because true values, and hence errors, are indeterminate.

- **Standard deviation, S:** the square root of the sample variance. It is calculated using the expression

$$S = \sqrt{\frac{\sum_{i=1}^{n} v_i^2}{n-1}} \quad \ldots\ldots (2.7)$$

Where S is the standard deviation, $n-1$ the degrees of freedom or number of redundancies, and, $\sum_{i=1}^{n} v_i^2$, the sum of the squares of the residuals. Standard deviation is an estimate for the standard error of the population. Since the standard error cannot be determined, the standard deviation is a practical expression for the precision of a *sample* set of data. Residuals are used rather than errors because they can be calculated from most probable values, whereas errors cannot be determined.

2.3.1 Precision versus Accuracy

Due to errors, repeated observation of the same quantity will often yield different values. A discrepancy is defined as the algebraic difference between two observations of the same quantity. When small discrepancies exist between repeated observations, it is generally believed that only small errors exist. Thus, the tendency is to give higher credibility to such data and to call the observations precise. However, precise values are not necessarily accurate values. To help understand the difference between precision and accuracy, the following definitions are given:

1. **Precision** is the degree of consistency between observations based on the sizes of the discrepancies in a data set. The degree of precision attainable is dependent on the stability of the environment during the time of measurement, the quality of the equipment used to make the observations, and the observer's skill with the equipment and observational procedures.
2. **Accuracy** is the measure of the absolute nearness of a measured quantity to its true value. Since the true value of a quantity can never be determined, accuracy is always an unknown.

2.3.2 Root Mean Square Error (RMSE)

Root Mean Square Error (RMSE) is a metric used to assess the amount of error in a regression or other statistical model. It measures the average distance between the predicted values from the model and the actual values in the dataset. The lower the RMSE, the better a given model is able to "fit" a dataset. Low RMSE values indicate that the model fits the data well and has more precise predictions. Conversely, higher values suggest more error and less precise predictions. When assessing how well a model fits a dataset, we use the RMSE more often because it is measured in the same units as the response variable. Conversely, the Mean Squared Error (MSE) is measured in squared units of the response variable.

2.4. Types of positional accuracy assessment of geospatial data

According to ISO standards, the geospatial positional uncertainty shall be reported separately in two components: horizontal and vertical. Reporting standards are a circle for horizontal uncertainty and a linear value for vertical uncertainty, both at specified confidence level (FGDC, 1998) (fig 2.1). It is accepted that the confidence level for reporting the uncertainty of geodetic control position is 95%.

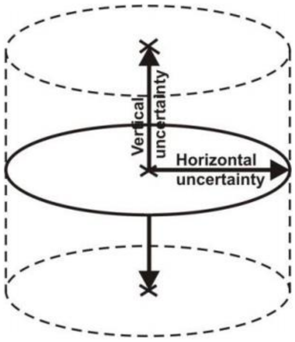


Figure2. 1 Circle for horizontal uncertainty and a linear value for vertical uncertainty

2.4.1 Horizontal positional accuracy assessment

The horizontal correctness of a map can be distinct as the RMS error in terms of the project's planimetric survey coordinates (X, Y) for test points as determined at full ground scale of the map. Therefore, the root mean square error is the aggregate outcome of all errors including those has got through the processes of ground control surveys, map compilation and final extraction of ground magnitudes from the map. As a result, evaluating for horizontal accuracy compliance is conducted by comparing the planimetric easting and northing coordinates of well-defined ground points. This data becomes compared with the coordinates of the same points which have obtained by a horizontal check survey of better accuracy. Briefly, the term well-defined points concerns to features that can be sharply recognized as separate points. Conversely, points which are not well defined (that is poorly-defined) are excluded from the intended accuracy investigation. In fact, poorly defined image points are features that do not have well-defined midpoints such as roads that intersect at narrow angles (U.S. National Map Accuracy Standards, 1941). In addition, Minnesota Department of Transportation, has Applied the NSSDA to evaluate the positional quality level of large scale data sets. The NSSDA needs to attain this; the horizontal and vertical RMSE is multiplied by 1.7308 and 1.96 factor respectively. The result becomes along in the horizontal and vertical accuracies of 0.181 and 0.134 meters respectively (Positional Accuracy Handbook (PAH), 1999).

2.4.2 Vertical positional accuracy assessment

Vertical accuracy has traditionally been, and currently still is, defined relative to the required contour interval for a map. In cases where digital elevation models (DEM) or digital terrain models (DTM) are being generated, an equivalent contour interval can be specified, based on the required digital point/spot elevation accuracy. The contours themselves may be later generated from a DEM using computer software routines. The ASPRS vertical standard also uses the RMSE statistic, but only for well-defined features between contours containing interpretative elevations, or spot elevation points. The limiting RMSE for Class 1 contours is one-third of the contour interval. Testing for vertical map compliance is also performed by independent, equal, or higher accuracy ground survey methods, such as differential leveling.

2.5. Google Earth

Google Earth **(**http://www.google.com/earth/index.html) (released in 2005) is the most influential virtual globe. It was originally called Earth Viewer 3D and was created by Keyhole, Inc., a company acquired by Google in 2004. User data can be incorporated into the system in a variety of ways, most notably using Keyhole Markup Language (KML). There are three versions of Google Earth, namely Google Earth Free, Google Earth Pro and Google Earth Enterprise, listed in rising order of supported capabilities. Google Earth Pro **(http://www.google.com/enterprise/earthmaps/earth_pro.html**) is business-oriented subscription-only upgrade to Google Earth Free that provides customers with additional features in GIS and remote-sensing (RS) data import, advanced measurement tools, higher data download speeds and higher resolution printing and movie making. Google Earth Enterprise is designed for use by organizations that have satellite imagery or large quantities of geospatial data that need to be deployed in a secure solution (e.g. run on their own hosting environment on their own servers) **(http://www.google.com/enterprise/earthmaps/earth_enterprise.html)**.

Google Earth was the first program able to view and graphically edit KML files. Nowadays, more and more virtual globes and GIS software support KML, especially after KML became an Open Geospatial Consortium (OGC) standard in 2008. KML has been the most widely embraced means by which scientific users create dynamic, interactive displays without the need to be GIS experts or computer programmers (Bailey and Chen 2011). Furthermore, a COLLADA (Collaborative Design Activity)-based 3D KML model has opened doors for vertical profile rendering in Google Earth. It improves the visualization effects for complex objects and phenomena.

2.5.1 Factors affecting positional accuracy of Google Earth

Due to the popularity of Google Earth as an application for map lovers, navigators and armchair explorers, users commonly assume that it is a credible and reliable source of information since it was released in June 2005 (Google., 2007). World level coverage of Earth is available by the superimposition of images obtained from satellite imagery, aerial photography, streets, points of interest and GIS 3D globe. This virtual globe is one of the most popular applications being used by both GIS and non GIS users. The Google Earth service has many tools that allow users to not only extract spatial data but also to add their own content to the imagery, such as photographs, landmarks and notes (Mohammed, 2013). Now, the high-resolution imagery that Google Earth hosts allows human observers to readily discriminate between major natural land cover classes and to discern components of the human built environment, including; individual houses, industrial facilities, and roads (Algarni, 2014).

2.5.2 Google Earth positional accuracy assessment in literature review

Freely accessible remotely sensed images in Google Earth facilitate (providing base map and/or validation) research in urban studies, disaster relief, natural resource management and so on. An evaluation of horizontal positional accuracies for Google Earth's images is 40 m RMSE (root mean square error) calculated from 436 points chosen worldwide (Potere., 2008). The accuracy of control points in more developed countries is 24.1 m RMSE, and 44.4 m RMSE in developing countries (Potere, 2008). A local investigation conducted by comparing virtually traced positions in Google Earth against high-precision (<1 m) field measurements along three stratigraphic unconformity sub-sections in Texas, USA, shows much better than the accuracies of the terrain model in Google Earth – 2.64 m RMSE horizontal and 1.63 m RMSE vertical (Benker, Langford, & Pavlis, 2011). These plausibly indicate that high-resolution imagery and the terrain model in Google Earth have sufficient horizontal positional accuracy for assessing moderate-resolution RS products across most of the world's urban areas. It also indicates that high-resolution images in Google Earth are sufficient for site validation, which is a difficult-to-accomplish requirement in global mapping.

(Kazimierz Becek and Khairunnisa Ibrahim, Brunei Darussalam et al.,, 2011), tested the Google Earth positional accuracy by using more than 1900 control points located in five continents in worldwide. The study concluded that the error could reach 1.5 km in some cases. (Nagi., 2013), Tested the Google Earth positional accuracy of 16 control points located in Khartoum state, Sudan. This was carried out by comparing Google Earth measured coordinates of control points with Global Positional System (GPS). Root Mean Square Errors (RMSE) for horizontal and height coordinates were found to be 1.59m & 1.7m respectively.

(Ahmed ., 2015), Tested the horizontal positional accuracy by 16 check point for the Ain Shams University. The check was started from preprocessing of GE image for the Ain Shams University to six well defined and sharp reference GCPs, in order to apply the required coordinate transformation. These reference points are selected from the AutoCAD map of study area. The ERDAS IMAGINE 8.4 software is used for georeferencing the image, were the Universal Transvers Mercator projection (UTM) was used with zone 36. The geometric model used is the second order polynomial and the resampling method used is the Nearest Neighbor to obtain the rectified image, within a resolution of 0.25 x 0.25 meter. The assessment depends on the discrepancies in the 2D planimetric ground coordinates (E, N) of all selected check point, which is simply the difference between the computed coordinates from both used Google Earth images and the actual reference ground coordinates. The obtained results was Horizontal positional accuracy of online Google Earth imagery for a certain study area located in Cairo varies between 5.89m and 15.68m, with RMS value of 10.58m. These findings agreed with many previous studies and investigations, but cannot be generalized to be valid and applicable elsewhere. This finally leads to a corresponding accuracy of 1.955m. This accuracy can successfully be used to derive planimetric maps with medium and small scales and may be applied in large scales with certain precautions. In all cases, the accuracy of measured distances is better than the corresponding accuracy of measured individual coordinates. Google Earth imagery has nearly a systematic positional shift. But, in general, Google Earth represents a powerful and attractive source of positional data that can be used for investigation and preliminary studies with suitable accuracy and low cost.

2.6. Research gap and knowledge

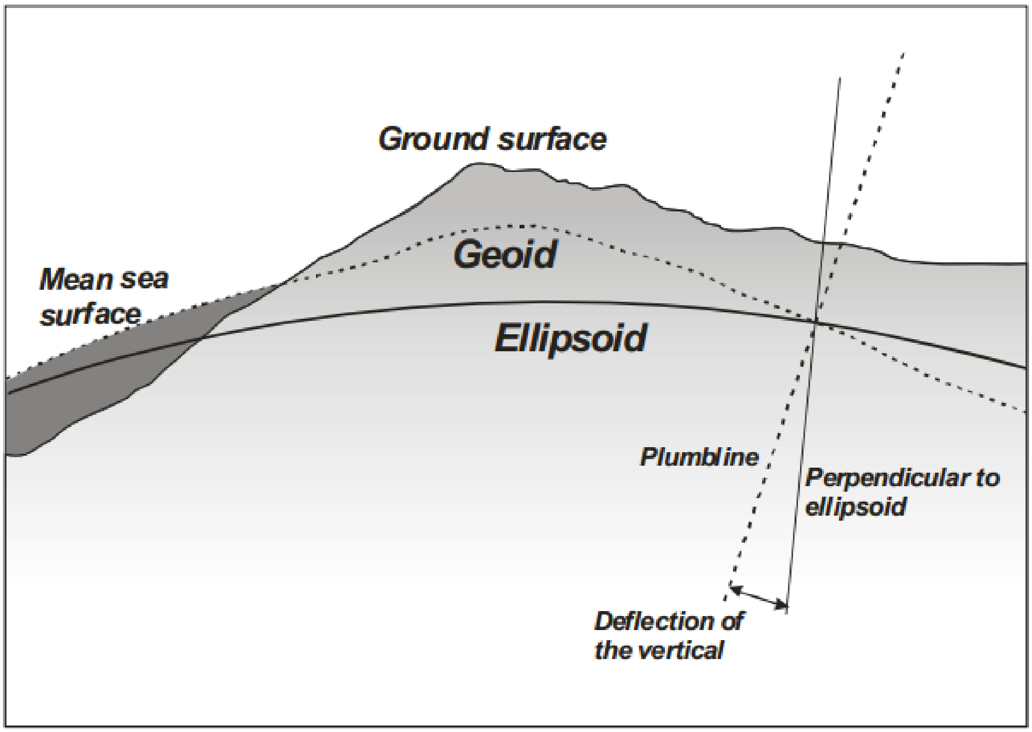
In general, the reviewed literatures measure the error in the positional accuracy of latitude, longitude and elevation of points in GE. However most of the above literatures test was only based on the GE which directly derived scene from the GE and also in country level except unpublished research based on this title was rare. Only one research which done in A.A published and reviewed for this study used as a reference in Ethiopia level. However this reference study was done only for one period of time; didn't consider the historical image accuracy evaluation (i.e. is the accuracy of GE imagery improving or not). As Adama city the nearest city for Addis Ababa city it seems that the positional accuracy of GE has no significant difference from positional errors of GE in Addis Ababa; but it is not because of significant elevation difference between these cities. Adama has lowest elevation when compared with Addis Ababa city. So this elevation difference were affected the positional accuracy of GE in Adama city. As the positional and resolution accuracy of GE imagery gradually we need to evaluate the positional accuracy of historical GE imagery to find the extent positional accuracy improvement from time to time. Except the last literature, the process of georeferencing was not done. Even the last literature only tested that horizontal position. This research will assess positional accuracy of GE by involving two main stages: the first stage is to investigate horizontal positional accuracy of GE by comparing the coordinates derived from GE with its GPS and TS coordinate. Second stage is to investigate the vertical positional accuracy of GE. To do this, historical imagery (images of years 2013 and 2023) of GE will be downloaded and georeferenced.

2.7. Conceptual framework

This research done by use of both raster (i.e. remote sensing data) and vector data (i.e. coordinate generated from GE imagery, GCP and Total Station coordinates and the distance measured from GE imagery and by field survey with the instrument of Total Station). The conceptual framework of this research categorized into three compositions which applied step by step. Reference data framing or like GCP adjustment, similarity transformation and georeferencing GE data, Statistical analysis of positional accuracies (i.e. calculation of coordinate difference between GE coordinate and GCP, and between GE coordinate and Total Station and comparing the horizontal distance difference between GE and Total Station) and comparing the GE discrepancy to standard values for practical use. In the first step reference data used for positional accuracy assessment is adjusted to determine accuracy level. Then GE coordinate should be transformed to GCP reference frame as the datum of all image data is WGS84 and georeferencing GE image. In second step shows the statistical components like misfit vector horizontal error/shifts calculation, distance difference calculation, RMSE calculation and Whole Circle Bearing (WCB) calculation. The last step shows analyzing accuracy improvement of GE image based on study period and comparing statistical errors of GE coordinates with standard values of ASPRS.

2.8. Reference Geodetic Datum

As per (Smith 1997) definition a geodetic datum is “the exact model of the earth: the size and shape of the earth and the origin and orientation of the coordinate systems used to map” (Smith, 1997). Traditionally, there are two types of datum are used: horizontal and vertical datum, based on ellipsoids and geoid respectively (Seeber, 2008). Horizontal Datum characterizes the relationship between the physical earth and horizontal coordinates such as latitude and longitude. The vertical datum may be a collection of particular points on the Earth with known heights either over or under mean ocean level. Particularly, to characterize a datum, the following will be required: An sign within the field (usually through a monument) of where the datum's beginning point (root) is found, the azimuth of a line interfacing the datum's beginning point to a secondary point, the exact definition of the model of the earth upon which the datum is based, and finally an amount known as the datum's geoid partition at the starting point. There are various sorts of transformation models and coordinate systems within the world. One commonly used datum to portray the whole earth is WGS 1984, which refers to the World Geodetic Framework of 1984. The best mathematical estimation of the shape and size of the Earth, on which coordinate systems, are based on ellipsoids and geoids (Ayer & Fosu, 2008). In common, the impact of a transformation on a 2D or 3D object will shift from a simple alter of location and orientation (with no alter in shape or size to a uniform alter scale factor), to changes of the shape and size of distinctive degrees of nonlinearity (Mikhail, 1982).



2.8.1 MSL, Ellipsoid and Geoid

- **Mean Sea Level (MSL): -**Mean sea level (MSL, often shortened to sea level) is an average surface level of one or more among Earth's coastal bodies of water from which heights such as elevation may be measured. The global MSL is a type of vertical datum, a standardized geodetic datum, that is used, for example, as a chart datum in cartography and marine navigation, or, in aviation, as the standard sea level at which atmospheric pressure is measured to calibrate altitude and, consequently, aircraft flight levels. A common and relatively straightforward mean sea-level standard is instead the midpoint between a mean low and mean high tide at a particular location.
- **Ellipsoid: -**Ellipsoids are the horizontal surfaces to which the geodetic latitudes and longitudes are referenced. Ellipsoid is that they fit the real shape of the earth as described by the geoid rather well and can thus be regarded as representative, yet simple, expression of the shape of the earth (Li & Götze, 2001). The ellipsoid has certain characteristics like it is, a mathematical definition, cannot be sensed by instruments, to be as close as possible (but not exactly) to the earth’s surface (or geoid) on a national or global point of view, described by two parameters (the

semi-major axis (for size) and the flattening (for shape)). Because the ellipsoid shape does not fit the Earth perfectly, there are lots of different ellipsoids in use.

- **Geoid: -**The geoid is the equipotential surface of the earth's gravity field that roughly approximates the mean sea level (Li & Götze, 2001). For height measurement above the earth surface a reference zero-height surface is required. This reference surface must be a level surface and for it to be used worldwide. The geoid has certain characteristics like, it is a physical definition, it can be defined by infinite number of parameters, it can be sensed by instruments, it is a complicated surface (irregular), it cannot be represented by any mathematical equation, and it enables users to determine the direction of water flow (Li & Götze, 2001).

2.8.2. Geocentric Horizontal Datum

In the last 15 years, satellite data has provided geodesists with new measurements to define the best earth-fitting spheroid, which relates coordinates to the earth's center of mass. An earth-centered or geocentric datum uses the earth's center of mass as the origin. The most recently developed and widely used datum is World Geodetic System-WGS84 (Geocentric Datum). It serves as the framework for location measurement worldwide.

2.8.3. Local datum/Topo-centeric datum

A local datum aligns its spheroid to closely fit the earth's surface in a particular area. A point on the surface of the spheroid is matched to a particular position on the surface of the earth. This point is known as the local origin point of the datum. The coordinates of the origin point are fixed, and all other points are calculated from it. In Ethiopia, the (Adindan, Adindan 4 datum), Clarke 1880 spheroid parameters, whose radii are 6,378,249.1 and 6,356,514.9 meters are in place and all maps produced by EMA uses this datum for preparation of all maps.

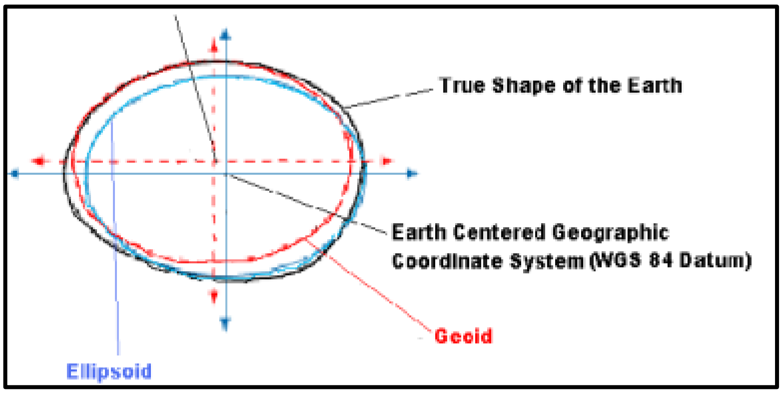


Figure2. 2 Datum (Origin of Map Coordinate Systems)

The coordinate system origin of a local datum (Adindan 4) is not at the center of the earth as WGS-84 datum. The center of the spheroid of a local datum is offset from the earth's center (Figure 2.4). Different Adindan local datum is shown in Table 2.1.

Table: 2. 1 Adindan Geographic (datum) transformations parameters and areas of use

Datum Name	Transformation Name	Area of use
Adindan 1	1100	Ethiopia, Eritrea and Sudan
Adindan 2	1101	Burkina Faso
Adindan 3	1102	Cameroon
Adindan 4	1103	Ethiopia
Adindan 5	1104	Mali
Adindan 6	1105	Senegal
Adindan 7	1106	Sudan

2.9. Coordinate system

To define a coordinate system we need to define: its origin (3 components), its orientation (3) components, and its scale (Dutton, 1999). The two coordinate types commonly used are ellipsoidal (geographic or curvilinear) coordinates (latitude, longitude and ellipsoidal height) and rectangular (Cartesian) coordinates - (XYZ).

2.9.1 Geographic Coordinate System (GCS)

The most commonly used coordinate system today is the latitude, longitude, and height system whereas, the prime meridian and the equator are the reference planes used to define latitude and longitude. The position of a ground point can be defined by its geographic coordinates (ϕ, λ, h) (Shortis & Seager, 1994).

Where,

- Geodetic latitude ϕ: it is the angle between the equatorial plane and ellipsoidal normal;
- Geodetic longitude λ: it is the angle between meridian plane at Greenwich and meridian plane;
- Ellipsoid height h: it is the height of the object above the reference ellipsoid along the ellipsoid normal (Sonier and Chaumet, 1974).

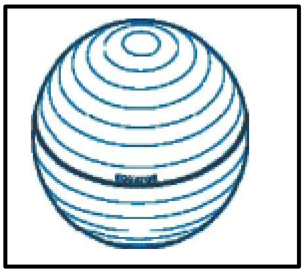


Figure2. 3 Latitude/Parallel lines

The line of zero longitude is called the prime meridian. For most geographic coordinate systems, the prime meridian is the longitude that passes through Greenwich, England. Other countries use longitude lines that pass through their capital city. Longitude values are measured relative to the prime meridian. They range from –180° when traveling west to +180° when traveling east. If the prime meridian is at Greenwich, then Australia, which is south of the equator and east of Greenwich, has positive longitude values and negative latitude values. The origin of the graticule (0, 0) is defined by a point where the equator and prime meridian intersect. The globe is then divided into four geographical quadrants that are based on compass bearings from the origin. North and south are above and below the equator, and west and east are to the left and right of the prime meridian (Figure 2.1and Figure 2.2).

Latitude and longitude values are traditionally measured either in decimal degrees (DDD.DDDDD°) or in degrees, minutes, and seconds (DMS). It may be helpful to equate longitude values with X and latitude values with Y. Data defined on a geographic coordinate system is displayed as if a degree is a linear unit of measure.

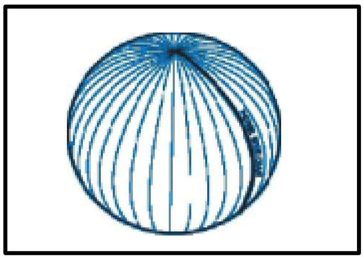


Figure2. 4 Longitude/Meridian lines

Although longitude and latitude can locate exact positions on the surface of the globe, they are not uniform units of measure. Only along the equator does the distance represented by one degree of longitude approximate the distance represented by one degree of latitude. This is because the equator is the only parallel as large as a meridian. Circles with the same radius as the spherical earth are called great circles. The equator and all meridians are great circles.

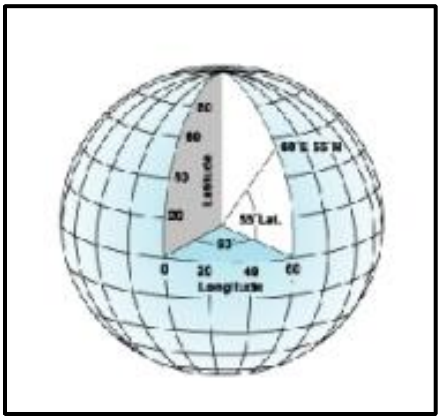
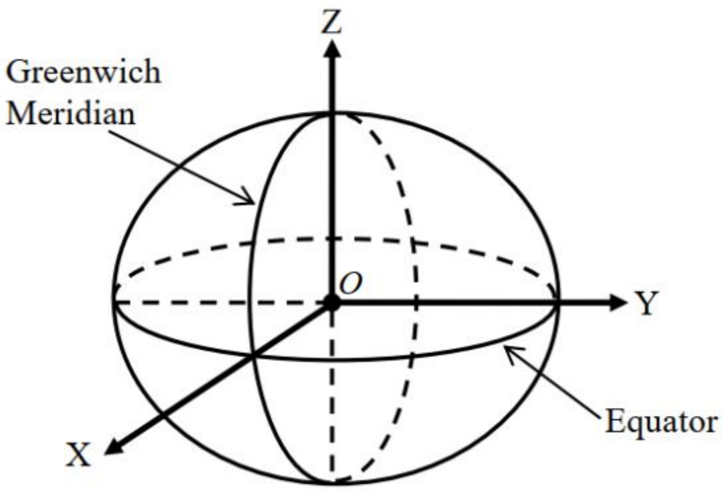


Figure2. 5 Graticule (Series of Latitude and Longitudes)

Above and below the equator, the circles defining the parallels of latitude get gradually smaller until they become a single point at the North and South Poles where the meridians converge. As the meridians converge toward the poles, the distance represented by one degree of longitude decreases to zero. On the Clarke 1880 spheroid model, one degree of longitude at the equator equals 111,321 meters, while at 60° latitude it is about 55,660 meters (111,321mX Cosine 60). Because a degree of latitude and longitude don't have a standard length, you can‘t measure distances or areas accurately or display the data easily on a flat map or computer screen.

2.9.2 Cartesian coordinate system (CCS)

It defines three- dimensional positions with respect to the center of mass of the reference ellipsoid. The X-axis is defined by the intersection of the plane defined by the prime meridian and the equatorial plane. The Y-axis completes a right- handed orthogonal system by a plane 90 degrees east of the X-axis and its intersection with the equator, and the Z-axis points toward the North Pole.



Currently, there are many different coordinate systems in the world, based on different kinds of geodetic datum's units, projections, and reference systems that are in use today. The datum can be global like WGS-84 and local like Adindan-Ethiopia. Generally, Coordinate systems can be defined in three, five, seven, eight, or ten parameters. The relationship between the rectangular Cartesian coordinates (x, y, *and* z) and geodetic coordinates (ϕ, λ, h) can be expressed in (Bowring"s, 1976) equations in equation (1) (Bowring, 1976) as:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{vmatrix} (N+h) \times \cos\phi \times \cos\lambda \\ (N+h) \times \cos\phi \times \sin\lambda \\ (N(1-e^2)+h) \times \sin\phi \end{vmatrix} \quad \ldots\ldots\ldots (2)$$

Where ''e" denotes the first eccentricity of the reference ellipsoid and „N' is the radius of curvature in the prime vertical at latitude ϕ.

Inverse computation from (ϕ, λ, and h) to (X, Y, Z) is complicated, for h is not in reference ellipsoid. Φ and λ and can be computed using closed formula of the Bowring"s (1976) equations as (Bowring, 1976):

$$\tan\phi = \frac{Z+\frac{a\times e^2}{\sqrt{1-e^2}}sin^3\theta}{p-a\times e^2\times cos^3\theta} \quad (2.1)$$

Where:

$$\tan\theta = \frac{z}{p\sqrt{1-e^2}} \quad (2.2)$$

$$\tan\lambda = \frac{y}{x} \quad (2.3)$$

2.10. Map projection

A map projection is a way to represent the curved surface of the Earth on the flat surface of a map. A good globe can provide the most accurate representation of the earth. However, a globe isn't practical for many of the functions for which it requires maps. Map projections allow users to represent some or the earth's entire surface, at a wide variety of scales, on a flat, easily transportable surface, such as a sheet of paper. Map projections also apply to digital map data, which can be presented on a computer screen.

There is three main type of surfaces that globe can be projected on. These include:

- Azimuthal (projection into a plane)
- Conical and
- Cylindrical

Universal Transverse Mercator (UTM) is a 'pseudo cylindrical' conformal projection (it preserves shape). The UTM system divides the earth into 60 zones each 6 degrees of longitude wide. These zones define the reference point for UTM grid coordinates within the zone. UTM zones extend from latitude of 80° S to 84° N. In the Polar Regions the Universal Polar Stereographic (UPS) grid system is used. UTM zones are numbered 1 through 60, starting at the International Date Line, longitude 180°, and proceeding east. Zone 1 extends from 180° W to 174° W and is centered on 177° W.

Each UTM zone is divided into horizontal bands spanning 8 degrees of latitude. These bands are lettered, south to north, beginning at 80° S with the letter **C** and ending with the letter **X** at 84° N. The letters **I** and **O** are skipped to avoid confusion with the numbers one and zero. The bands lettered **X** spans 12° of latitude Where, Sudan falls in zone 36N.

Scale factor is the ratio of any two corresponding lengths measured between two points (i.e. projected and actual length). In UTM the default scale factor value is (o.9996) m.

Practically, for each region of the earth there is a suitable map projection (i.e., in the poles the adopted projection is the UPS system), in the same manner, for each country there is a suitable datum, which is a reference for position on the surface of the earth.

Table: 2.2 UTM Projection Coordinate Code System and Area of Use

Projected coordinate system	Code	Area of Use and coverage
Adindan UTM Zone 36N	20136	Ethiopia: West of 36°E; Sudan: 30°E to 36°E
Adindan UTM Zone 37N	20137	Ethiopia: 36° E to 42°E
Adindan UTM Zone 38N		Ethiopia: East of 42°E

Source: Adapted from ArcGIS 9.3.1 Manual. (2008) ESRI

CHAPTER III: MATERIALS AND METHODS

3.1 Description of study area

3.1.1 Location of study area

Adama is a city in Ethiopia's central Oromia Region. Adama is part of Oromia's Special Zone and is surrounded by the East Shewa Zone. It spans 8°26'15"−8°37'00"N latitude and 39°12'15"−39°19'45"E longitude, covering a total area of 134.11 km2 and at an average elevation of 1712 meters above mean sea level (Figure 3.1). To the west, the city is at the base of an escarpment, and to the east, the Great Rift Valley. Since its founding in 1916, the City's quick progress, as well as its infrastructure, has been aided by its good geographical location, which is close to the capital city of Addis Ababa, and its pleasant climatic conditions.

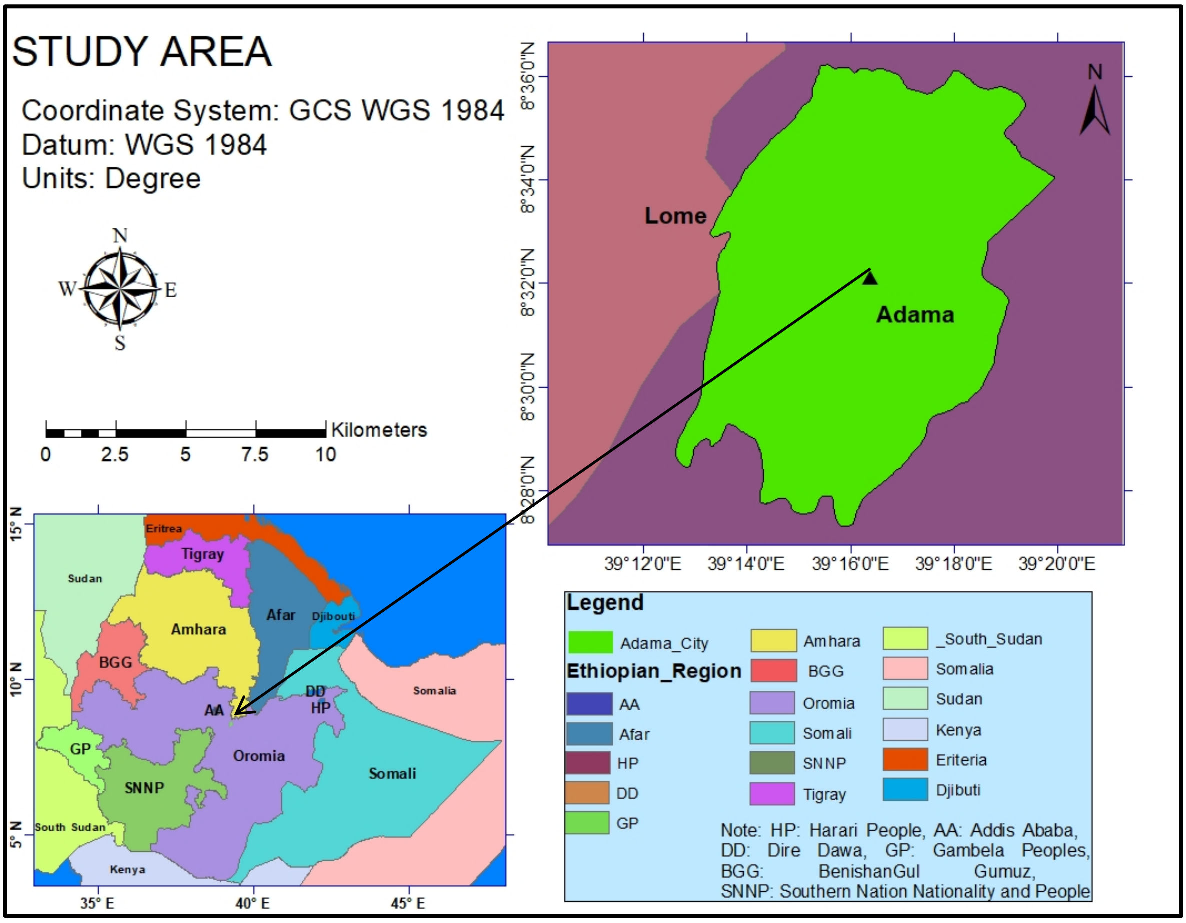


Figure: 3. 1 Map that shows study area (Adama city)

3.2 Data used for this research

As the main goal of this study was assessment of horizontal and vertical positional accuracy of Google Earth and most of data used were position related data. Here it needs the following major data that were collected and used in the process of the analysis. The data for the projects are listed in the following tables.

Table: 3. 1 Types and source of data used for this research

Data	**Source**	**Format**	**Acquisition year**
GCP	From Adama city land administration	Vector	2022
Total Station points	Field observation ASTU environment	Vector	2022
GE Imagery	From GE imagery Website	Raster	2013 & 2013
Satellite Imagery	Sentinel-2 and USGS	Raster	2013 & 2018
Adama city shapefile	From Adama city land administration	Vector	2022
AW3D30 DEM	From USGS earth explore	Raster	2022

3.3 Software and materials used in this research

In order to achieve the objectives of this research the following Software were used. The materials and software that used to collect all necessary data, to process and analyze in this thesis are listed in the table below:

Table: 3. 2 Software and materials for this research

Name	**Type**	**Function**
HHGPS	Material	For tracking GCP
Computer	Material	To store, report writing and for data analyze
Total Station	Material	To measure coordinates for validation
QGIS 10.5	Software	For processing, analysis and visualization of spatial data
GE	Software	To drive check point or GE coordinate
Microsoft office	Software	For analysis, presenting and reporting the finding
GPS Software	Software	Used as a bridge between GPS data and GE
ERDAS Imagine	Software	For georeferencing remote sensing data

3.4 Methods of data analysis

In this study, by statistical method the horizontal and vertical positional accuracy of Google Earth of collected data through desk review and ground survey will be assessed.

This was done by comparing the coordinates of selected GCP derived from GE with its adjusted true ground control point (GCP) measured by Dual GPS (DGPS) and Total Station coordinate in the environment of ASTU.

In addition to GPS coordinate and GE, (ALOS) World 3D - 30m (AW3D30) DEM was used to extract elevation value of GE mark through Arc GIS. In 2015, the Advanced Land Observing Satellite (ALOS) World 3D - 30m (AW3D30) DEM was made available as an Earth topography elevation data product AW3D30 was Photogrammetrically developed using optical imagery collected during the ALOS mission (Tadono, 2016). The ALOS elevation maps were produced at a spatial resolution of 5m with an accuracy of 5m (standard deviation). In 2016, JAXA released a 30m product, the AW3D30 dataset which was generated from the earlier 5m product (JAXA 2017). From the accuracy assessments by (Caglar, 2018), the AW3D30 surpassed the accuracies of SRTM and ASTER GDEM Version 2.

3.4.1 Sample selection techniques

Samples should be representative in order to powerfully represent the entire data sets. Therefore, for better result in positional assessment study, the sample must fulfill that enough number of points, well distribution, accuracy of theses common points and the transformation technique adopted. For this study the GE control points was taken from hilly and flat area with respect to GCPs which measured by GPS through Adama city land administration for the case study. From Adama city land administration office 142 GCPs where taken. From 142 GCPs 22 GCPs where selected based on well distribution i.e. by considering the configuration or based on elevation of the terrain. First recoding and filtering GCPs data was done by using SPSS software. The data was recoded into three groups. From those groups sample selection was done.

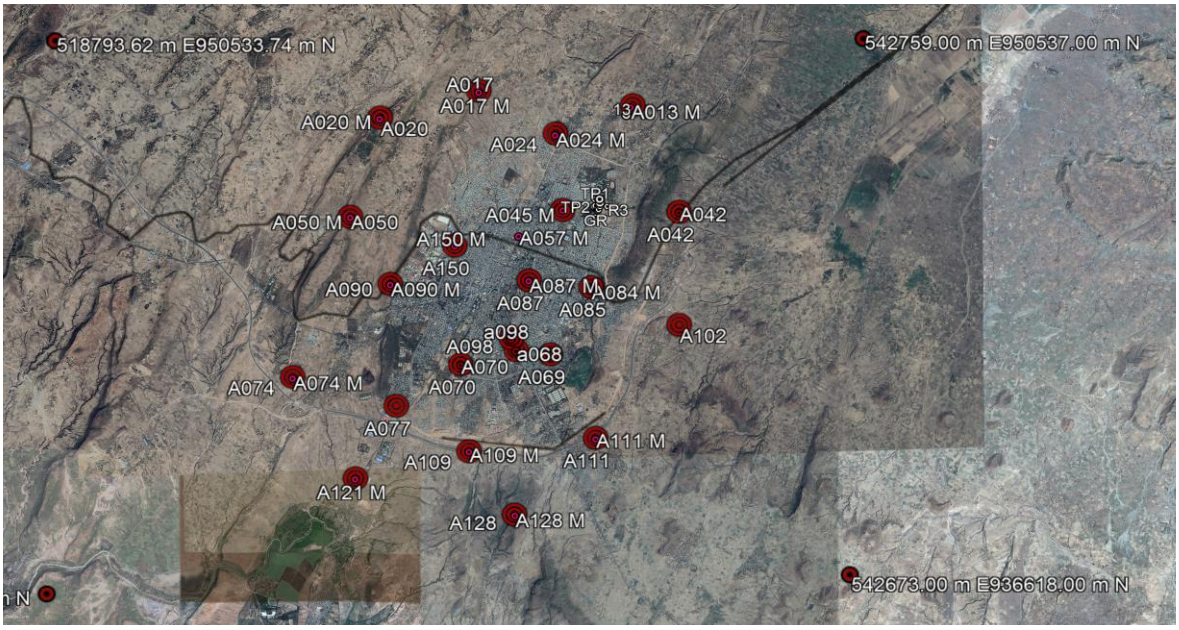


Figure: 3. 2 Google Earth images of year 2013

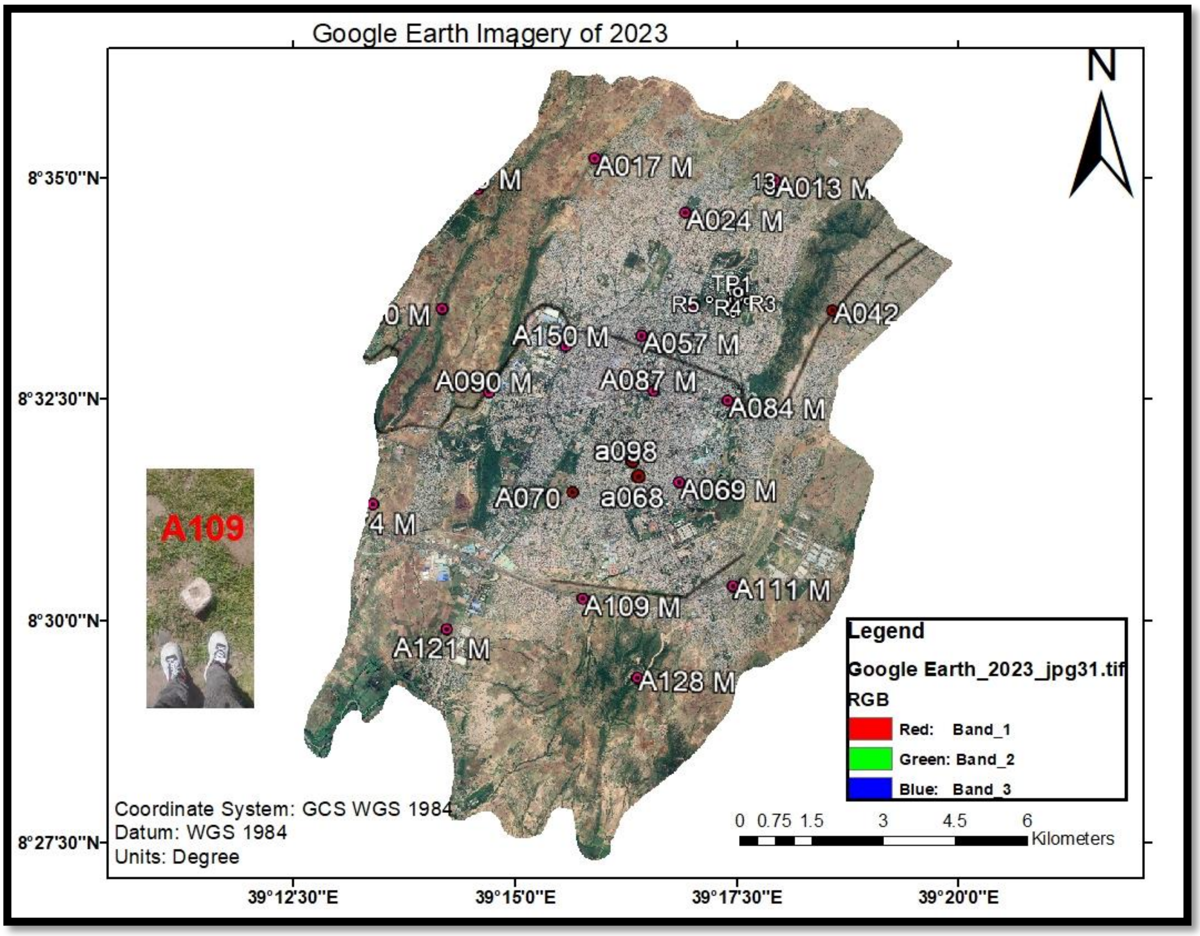


Figure: 3. 3 Google Earth Imagery of Adama city 2023

3.4.2 Field data collection

This step shows that activities which starting from GCP tracking by using HHGPPS and identifying the most probable visible control station on GE imagery; to coordinate and distance measurement on the ground by using Total Station in the environment of ASTU. The coordinate measurement was taken by using REX-Total station which borrowed from ASTU Geomatics Engineering department. To do this reconnaissance map was produced from GE. The most visible stations are selected on the GE, after that starting points or BM was taken Mesay Construction Company which established inside ASTU for road project. Starting from the BM 15 station coordinates was measured around graduation hall.

Figure: 3. 4 Shows field work on Ground Control Point tracking

After sample data was selected Ground Control Point monument or station tracking was done by using HHGPS. This step was very difficult because of the accuracy of HHDPS is very low, some of the monuments was also destroyed and it was difficult.

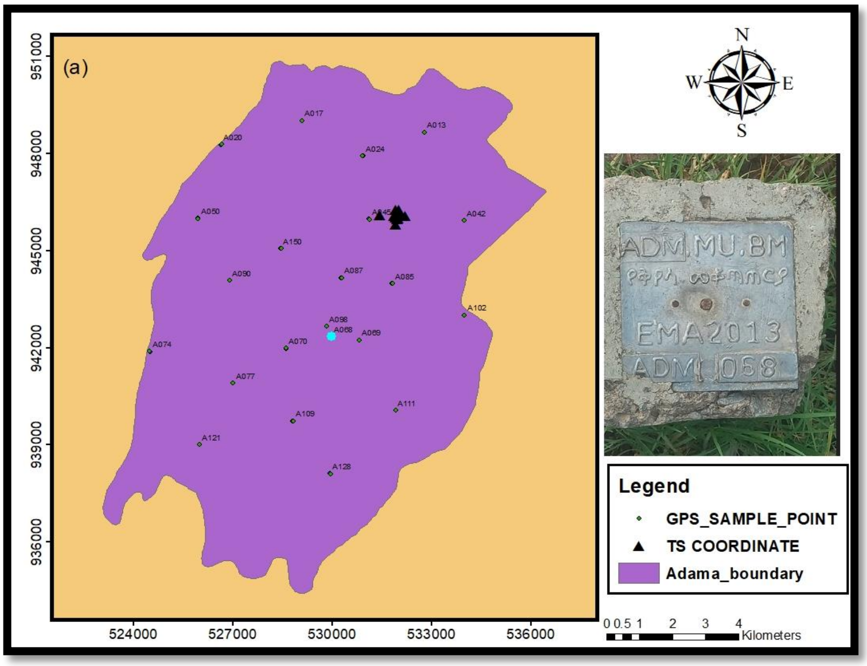


Figure: 3. 5 GPS GCPs and TS coordinate distribution over the study area

On the figure 3.5 the point which has blue bold was established as BM or project control point by former Ethiopia Map Agency (EMA) and currently change its name to Institute of Geospatial Science (IGSS). This point was founded by point tracking using HHGPS and located around publicly known as a name of Muger. A068 is the assigned ID Name of station.

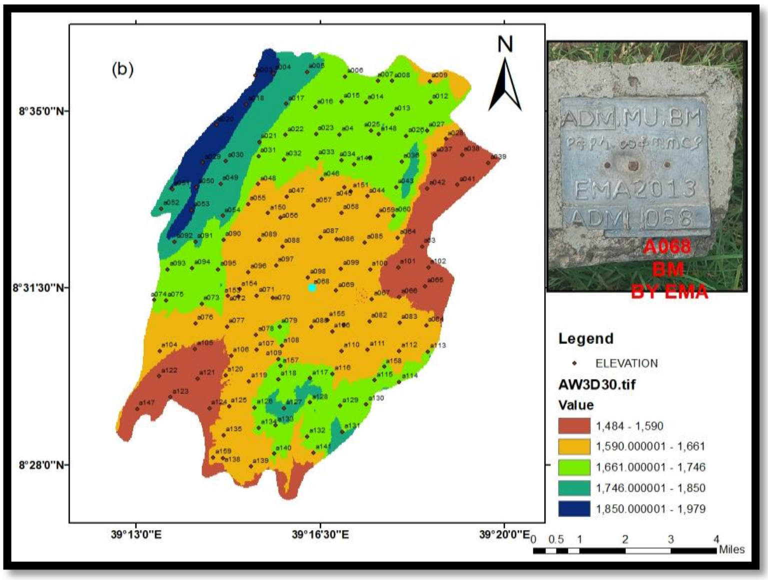


Figure: 3. 6 GPS Elevation and GE Elevation extracted from AW3D-30 DEM data

The above figure 3.6 shows that a map of raster data of AW3D-30m DEM and vector data of 3D (X, Y, Z) coordinates of study area.

3.4.3 Coordinate measurement from GE

In this part coordinates and distance was measured properly. In the process of check point selection we tried to overcame to minimize errors which occurred based on terrain configuration, well distribution of check point station selection was done, and inter visibility of check point station to the ground for Total Station measurement considered. For comparison GE coordinate with Total Station coordinate 17 control points and two horizontal distances was taken from both imagery data and ground measurement data.

Check point on the GE was marked carefully. So marking was done on visible features like poles, building corners, road corner or intersection and on white markers on the road for simply place or station marking on the GE imagery which was marked and measured on the ground by using Total station. The horizontal measurement was done by use of Total Station for on the ground measurement and Rural instrument was used for on GE horizontal distance measurement. Both distance converted into the same scale. For assessment of positional accuracy of GE with the data of GCP, which taken from the Adama city municipal, marking of check point was done on the most probable visible area of GCP of the ground. For all coordinates (i.e. GCP, Google Earth Check Point (GECP) and by Total Station measured coordinates) similarity transformation activity was done. For GCP and any BM adjustment was done.

For HPAA of GE with respect to GCPs, firstly all sample points was tracked located on the ground. Then carefully marking the located sample points on the same area of Google Earth was done. Then open the properties of each marked point and copy the values of longitude and latitude. By time slider on GE Pro for both years of 2013 and 2023 measurement was taken.

3.5. GPS data reliability test or GCPs validation

Table: 3. 3 Reference data that used for GPS data reliability test

Collected GCPs in WGS84			
LONGITUDE	LATITUDE	ELEVATION	NAME
12° 31' 19.2000" E	37° 29' 27.6000" N	2136.321	GONDAR
11° 48' 32.4000" E	38° 14' 24.0000" N	3112.919	TIE
8° 09' 18.0000" E	35° 33' 00.0000" N	2018.633	GORE
10° 03' 00.0000" E	34° 33' 07.2000" N	1661.317	ASSOSA
9° 06' 10.8000" E	37° 19' 15.6000" N	3045.124	TULU
9° 51' 36.0000" E	38° 37' 19.2000" N	3318.881	ELIN
9° 01' 55.2000" E	38° 15' 54.0000" N	2497400	WOLONK
7° 02' 16.8000" E	38° 28' 04.8000" N	1812.325	TABOR
12° 57' 03.6000" E	36° 10' 26.4000" N	820.01	METEMA
9° 02' 02.4000" E	38° 45' 53.6400" N	2436.689	BM1

Source: GII in [Ahmed A.W. and Mergia W.A. 2009]; Green Book, 1961 and GPS Survey, 2019

Table 3.5 shows that data used for validation of reference data. The validation was made by using EZ@SUR Micro Survey software. EZ@SUR is software developed by MicroSurvey Software. It provides a reliable and efficient RTK offline solution to improve the accuracy of your survey or GIS data. Although I don’t have detailed information about the software, it is designed to enhance the accuracy of your GIS data. However, it is always recommended to consult the official website of MicroSurvey Software for more information about the software’s capabilities and features. This software validates GPS data from reference of international base stations. While in our country there no international base station which established by NGA. International base stations are accessibly to any one from NGA website. For this study national base stations are used which taken from studies and checked by Green Book. The reference data or GCPs were analyzed by using this software with respect to validation data on table 3.3. Therefore the reference data fulfilled the standards to validate the test data.

3.6. Horizontal positional accuracy assessment

The coordinate differences between the GPS reference points and the coincident points on the Google Earth images were used as a basic metric in assessing the horizontal accuracy. Coordinates of points on the GPS were subtracted from those of the various epochs for the GE historical imagery. The differences in Easting and Northings are given as follows:

$$\Delta E = E_{GE} - E_{GPS\ or\ TS} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (3.1)$$

$$\Delta N = N_{GE} - N_{GPS\ or\ TS} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (3.2)$$

Where,

ΔE and ΔN are the differences in Easting and Northings respectively for the selected points. E_{GE} and $E_{GPS\ or\ TS}$ are Easting of selected points on the GE historical imagery and GPS respectively. N_{GE} and $N_{GPS\ or\ TS}$ are Northings of selected points on the GE historical imagery and GPS respectively. The linear separation between the position of a point on the GPS, TS and on Google Earth is the horizontal error/shift (S) (Figure 3.2).

The assessment of the horizontal accuracy is based on the ASPRS Positional Accuracy Standards for Digital Geospatial Data version 1.0 (ASPRS, 2014). Horizontal accuracy was assessed using Root Mean Square Error (RMSE) statistics in the horizontal plane (i.e., RMSEx, RMSEy, and RMSEr), while the vertical accuracy was assessed in the z-dimension. In addition, the standard deviation (SD) and standard error of the mean (SEM) of the coordinate differences were also calculated.

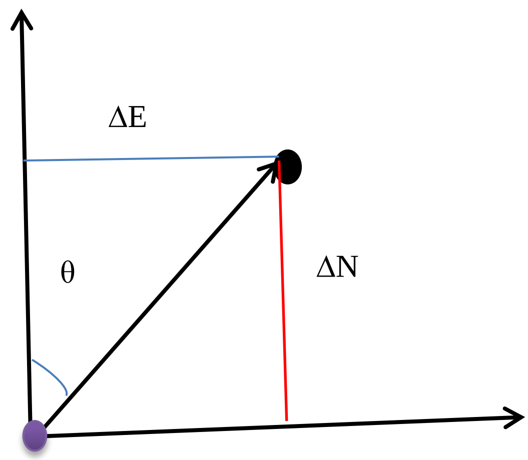


Figure: 3. 7 Graph show that of horizontal error between a point on the reference GPS, TS and GE. The origin point shows GPS station and the point shows GE station.

ASPRS (2014) defines positional accuracy as “the accuracy of the position of features, including horizontal and vertical positions, with respect to horizontal and vertical datum.” Based on the ASPRS recommendations for imagery at an estimated pixel size of 60cm, the Google Earth images used in this study are expected to meet the ASPRS Accuracy Standards of 120cm RMSEx and RMSEy Horizontal Accuracy Class for Standard Mapping and GIS work. The absolute horizontal accuracy should be less than or equal to 2.448 * 120cm at the 95% confidence level. The corresponding estimates of horizontal accuracy at the 95% Confidence level were computed using methodologies documented in the National Standard for Spatial Data Accuracy (NSSDA). The ASPRS standards for vertical accuracy specify absolute vertical accuracy measures for various classes of elevation data based on their spatial resolution (ranging from 1cm to 333.3cm). However, due to the uncertainty surrounding the source of GE elevations including its resolution characteristics, the vertical accuracy assessment is based solely on the reference GCPs. It was computed using the RMSE statistics for non-vegetated terrain (most of the 156 GCPs are located in non-vegetated terrain).

The horizontal RMSE (RMSEr) is given as:

$$RMSE_r = \sqrt{(RMSE_X)2 + (RMSE_Y)2} = \sqrt{\frac{\sum[\Delta E^2 + \Delta N^2]}{n}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (3.3)$$

$$RMSE_X = \sqrt{\frac{\sum(E_{GE} - E_{\frac{GPS}{TS}})2}{n}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.4)$$

$$RMSE_Y = \sqrt{\frac{\sum(N_{GE} - N_{GPS/TS)2}}{n}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. (3.5)$$

Where:

RMSEr = Root Mean Square Error of both X and Y direction

RMSEx = Root Mean Square Error in X direction

RMSEy = Root Mean Square Error in Y direction

EGPS or TS = Easting of GPS and Total Station

EGE = Easting of Google Earth

NGPS or TS = Northing of GPS and Total Station

NGE = Northing of Google Earth

ΔE = Change in Easting

ΔN = Change in Northing

3.6.1. Magnitude and Whole Circle Bearing (WCB)

Whole circle bearing and magnitude were calculated from horizontal error or change in Easting and Northing. For this the equation listed below was used:

$$Direction\ of\ horizontal\ shift\ (\theta) = \tan^{-1}\frac{\Delta E}{\Delta N} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (3.6)$$

$$\begin{aligned} WCB = \ \theta\ in\ quadrant\ one, WCB = 180° - \theta\ for\ quadrant\ 2, WCB \\ = 180° + \theta\ for\ quadrant\ 3\ and\ WBB \\ = 360° - \theta\ for\ quadrant\ four \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.7) \end{aligned}$$

$$Magnitude\ or\ Horizonta\ errororshift\ (S) = \sqrt{(\Delta E)^2 + (\Delta N)^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots . (3.8)$$

3.7. Vertical positional accuracy assessment

In this study to evaluate vertical accuracy of GE was done with respect to independent data (i.e. GCP of 142 stations). First the reference data was imported into Global Mapper and exported in KML file format. The exported data were opened in GE Pro and by using add place mark tool of GE to mark the points along the imported data. Subsequently, the height of marked points were saved and imported into Arc GIS. Then, the data was converted into shapefile to generate coordinate values of test data. All statistical analysis was performed in SPSS version 23. Data analysis performed includes, correlation analysis between reference and G.E. data, t-test of means with assumption of normality, Non-parametric correlation analysis test was also performed.

The accuracy assessment procedure adopted for this study is similar to those in (Arungwa, 2018) Vertical accuracies of the G. E. Elevation dataset are assessed by comparing them to ground point whose elevations were determined by the Total station equipment and GPS. In this study also, robust statistical test & accuracy indicators were deployed. The following statistical measures were applied to assess the error in G.E. dataset (Wessel et al 2018).

$$Mean\ Error\ (ME) = \frac{1}{N}\sum_{i=1}^{N} GE_H - GPS_H = \frac{1}{N}\sum_{i}^{N} \Delta H \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (3.9)$$

$$Mean\ Error\ (ME) = \frac{1}{N}\sum_{i=1}^{N} GE_H - TS_H = \frac{1}{N}\sum_{i}^{N} \Delta H \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.10)$$

$$Root\ Mean\ Square\ Error\ (RMSE) = \sqrt{\frac{1}{N}\sum_{i}^{N} (\Delta H)^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.11)$$

$$Standard\ Deviation\ (SD) = \sqrt{\frac{1}{N-1}\sum_{i}^{N} (\Delta H - ME)^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.12)$$

Δh is the difference calculated from the difference between corresponding height values from G.E. GPS and total station height. Positive differences represent locations where the G.E. elevation exceeded the total station elevation; and, conversely, negative errors occur at locations where the G.E. elevation was below the total station elevation (Santillan, 2016)

While the ME gives an overall idea in of the average bias in in G.E. dataset, the SD and RMSE measures G.E. dataset quality and provide insight into the distribution of deviations on either side of the mean value (Athmania, 2010). The level of agreement between G.E. and reference dataset were evaluated using parametric and nonparametric correlation analysis.

Table: 3. 4 coordinates which measured by Total Station and from GE software.

By Total Station				From GE software		
E	N	Elevation	ID	E_{GE}	N_{GE}	Elev of GE
532031.974	946268.274	1670.84	TP1	532123	946474	1674
532044.323	946173.677	1668.332	TP2	532135	946380	1672
532034.71	946077.773	1667.289	TP3	532126	946283	1670
531922.599	946018.335	1664.563	TP4	532017	946228	1665
531882.018	946083.266	1665.71	TP5	531982	946287	1667
531923.14	945807.31	1660.845	R1	532015	946008	1662
531918.812	946100.581	1665.462	R2	532012	946305	1667
532221.281	946081.102	1676.002	R3	532315	946289	1677
531915.024	946265.613	1669.287	R4	532009	946468	1671
531441.57	946096.252	1662.631	R5	531534	946301	1664
531947.489	946022.664	1664.562	GCO	532042	946231	1666
531982.66	946021.041	1665.241	GC	532077	946225	1667
532002.681	945998.856	1665.521	GR	532097	946205	1667
531984.284	945972.342	1664.671	BC1	532074	946179	1666
531969.674	945975.048	1664.671	BC2	532062	946179	1666

Table: 3. 5 GCP and GE coordinates measured from the image uploaded in 2013

	GPS data		2013 of GE data	
Name	Easting	Northing	Easting	Northing
A013	532781.229	948643.002	532800.964	948669.37
A017	529078.537	949014.632	529051.412	949020.368
A020	526640.996	948262.39	526672.021	948291.274
A024	530934.842	947914.527	530936.591	947939.489
A042	533998.883	945922.065	533996.102	945929.412
A045	531119.565	945967.333	531113.498	945967.114
A050	525947.374	945995.66	525938.006	945963.996
A068	529970.643	942333.069	529967.628	942333.911
A069	530809.356	942227.794	530812.066	942229.488
A070	528602.278	941967.078	528599.839	941966.904
A074	524483.185	941871.047	524466.844	941844.015
A077	527005.488	940890.489	527000.499	940892.241
A085	531814.78	943974.553	531817.45	943976.401
A087	530275.247	944145.913	530283.351	944145.716
A090	526893.774	944067.661	526868.816	944050.666
A098	529839.279	942652.697	529844.82	942646.145
A102	534004.392	942992.965	534001.211	942997.455
A109	528809.171	939724.954	528807.714	939723.074
A111	531925.531	940053.685	531930.139	940064.956
A121	525984.706	938996.715	525985.394	939006.33
A128	529936.357	938106.797	529938.205	938101.144
A150	528446.038	945057.929	528448.585	945043.322

Table 3.4, 3.5, and 3.6 shows coordinate values measured by TS and measured from GE, GPS data and GE coordinate of year 2013, and GPS data and GE coordinate of year 2023 respectively.

Table: 3. 6 GCP and GE coordinates measured from the image uploaded in 2023

	GPS data		2023 of GE data	
Name	Easting	Northing	Easting	Northing
A013	532781.229	948643.002	532786.861	948635.857
A017	529078.537	949014.632	529078.62	949014.552
A020	526640.996	948262.39	526645.8049	948274.9856
A024	530934.842	947914.527	530922.942	947912.769
A042	533998.883	945922.065	533990.859	945915.044
A045	531119.565	945967.333	531126.953	945960.061
A050	525947.374	945995.66	525943.173	945980.643
A068	529970.643	942333.069	529970.686	942345.992
A069	530809.356	942227.794	530815.128	942222.427
A070	528602.278	941967.078	528598.001	941972.431
A074	524483.185	941871.047	524476.991	941884.788
A077	527005.488	940890.489	527005.64	940890.4
A085	531814.78	943974.553	531817.757	943984.558
A087	530275.247	944145.913	530278.459	944146.941
A090	526893.774	944067.661	526893.872	944057.572
A098	529839.279	942652.697	529839.313	942652.59
A102	534004.392	942992.965	533998.347	942999.37
A109	528809.171	939724.954	528811.689	939722.462
A111	531925.531	940053.685	531933.205	940052.367
A121	525984.706	938996.715	525975.646	939010.415
A128	529936.357	938106.797	529945.968	938098.784
A150	528446.038	945057.929	528454.388	945051.311

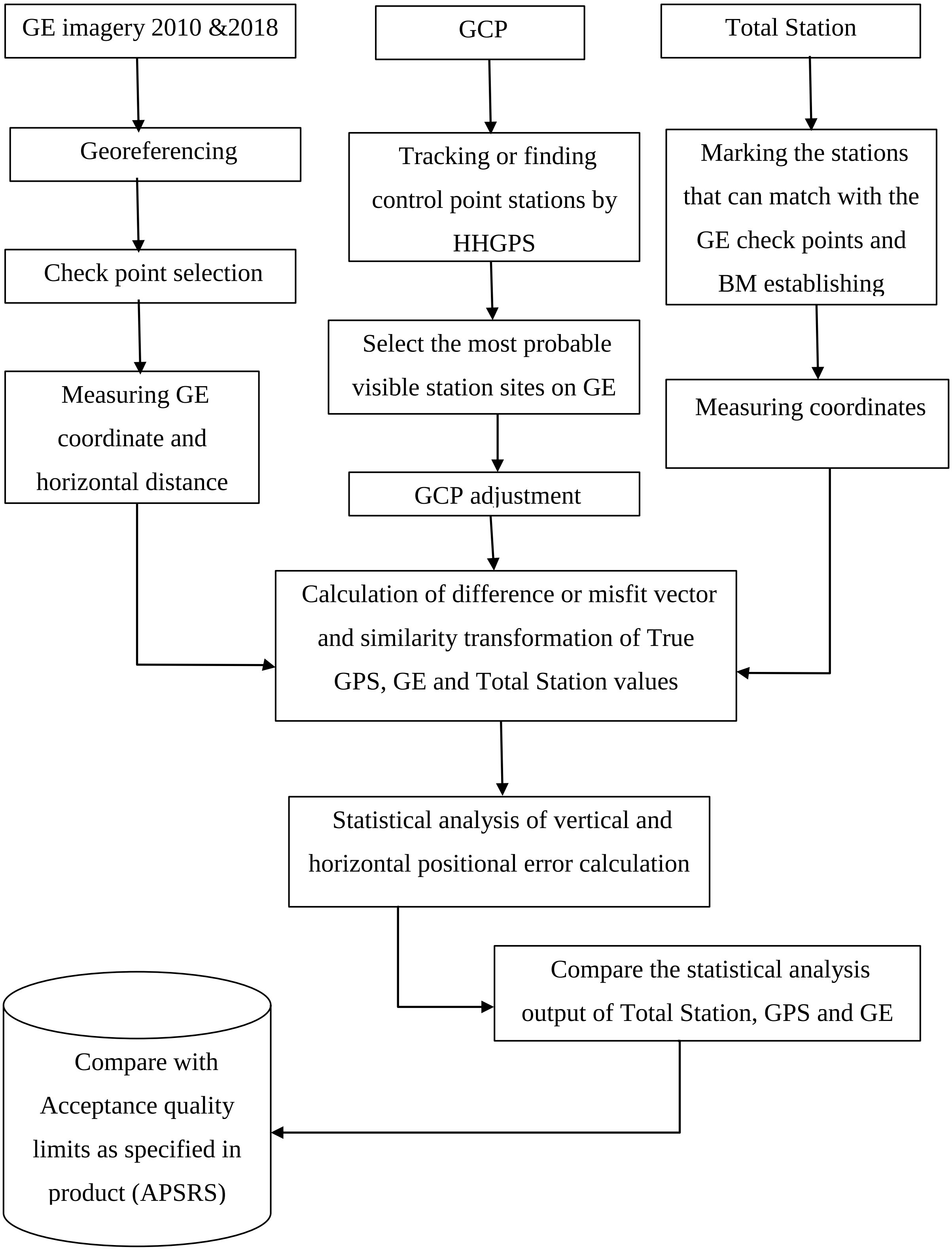


Figure: 3. 8 Flow chart that show sequences of methodologies applied in the study

3.8. Basics on Global Positioning System (GPS)

Global Positioning System (GPS) is a system in which a satellite continuously transmits coded information, which makes it possible to precisely identify locations on earth by measuring distances from satellites. GPS has a variety of applications on land, sea and in the air. This chapter provides the basics and background on how the GPS operates and the errors that are involved in it.

In the 1970s, the U.S. Department of Defense (DoD) developed and began deploying a satellite-based system to provide military positioning, navigation, and weapons-aiming capabilities —GPS. By 1993, the DoD had launched 24 satellites (plus three backups) to fully implement the GPS system. The first use of GPS was exclusively for military purpose, but its application for civilian use soon followed in 1984. This technology is now available to everyone, everywhere, at any time and, best of all, at least/no cost. GPS operates 24 hours a day in all weather conditions, and can be used world-wide for precise navigation on land, on water and even in the air. GPS is a navigation system made up of three segments

- **A space segment:** includes the 24 GPS satellites in 6 orbital planes**.**
- **A control segment:** includes the ground monitor command and control function. It performs the tracking, orbital determination, and time synchronization function.
- **A user segment:** includes GPS receiver, which tracks the satellites and identifies the individual satellites. The receiver decodes the satellite signals and computes the position such as latitude, longitude, and altitude.

3.8.1 Differential Global Positioning System (DGPS)

A DGPS is a method of improving the accuracy level of GPS receivers by adding a local reference station to augment the information available from the satellite. To offset the effects of GPS errors and to increase the overall accuracy of GPS units, a system called Differential GPS (or DGPS) is used. Differential GPS increases the accuracy of GPS positions by reducing atmospheric and satellite errors. It contains a base station with known location. Differential correction can be applied in real (time directly in the field) or post–processed in the office. The DGPS system uses GPS receivers accurately placed at known locations (base station). Base station GPS receivers constantly calculate the error between location determined from GPS signals and its known location. The differential corrections are then applied to the GPS receivers ‘calculations, removing many of the common errors and improving accuracy.

The base station receiver determines the error components and provides corrections to the GPS receivers in real times. Today, users do not need to establish their own base stations to obtain DGPS. There are several sources for DGPS correction signals that enable DGPS-equipped receivers to function over wide areas. The differences in these sources lie in the delivery methods and reliability of the DGPS signals.

3.9. Positional accuracy standards

Given the importance of positional accuracy in cartographic products, its assessment has been of interest since the development of science-based cartography. Therefore, several methods have been proposed and applied for this purpose throughout the 20th century (Ariza-López FJ, Atkinson AD, 2008a). These methods are referred to here as ‘standards’ as many of them are so named (e.g., the National Map Accuracy Standard, Engineering Map Accuracy Standard, and National Standard for Spatial Data Accuracy). These are standards and not norms, since almost none of them were developed by a standardization organization, and derive from professional associations or administrative bodies in the cartographic sector. The exception is UNE 148002, which bases its section on statistics on two other international standards of ISO.

As it is impossible to assess the positional component of 100% of the objects of a data product, a sample is also worked on and, therefore, the statistical method applied should be robust and reliable in all matters related to sampling to ensure the representativeness and validity of the results. This is related to the possibility of applying assessment methods focused either on quality estimation or quality control:

- **Estimation methods.** These are intended to reliably establish the value of a quality parameter (e.g., mean bias, standard deviation, proportion, etc.) regarding the population of interest. These methods provide a value and its corresponding confidence interval as a result (e.g., a mean value and its deviation such as 5.27m ± 0.15 m). The sample size is linked to the population size, and a larger population size requires a larger sample size, although there is an asymptotic behavior in the latter with respect to population size.

- **Control methods.** These are intended to provide a statistical basis for making an acceptance/rejection decision as a consequence of compliance/non-compliance with a specification. For example, given the specification that no more than 5% of the elements present 2D positional errors greater than 1 m, a decision is made to accept/reject according to the evidence found in the sample, trying to minimize type I (producer's risk, that is, to reject a data set that meets the specifications) and type II (user's risk, that is, to accept a data set that does not meet the specifications) errors. In this case, hypothesis testing techniques are applied and, therefore, the sample size is not directly linked to the population size. A random sample size ensures type I errors are adequately controlled, although a specific sample size is required to ensure that type II errors are avoided.

Both the sample size and its distribution (spatial, thematic, and temporal) and randomness are key elements to ensure the representativeness and validity of the results. In addition, from a statistical point of view, there are two types of methods:

- **Parametric based.** These methods assume that the positional errors under analysis conform to a parametric statistical distribution function, which is known. It is common to assume the normal distribution, in which case the mean (location parameter) and the standard deviation (scale parameter) are applied. These are currently the most frequently used methods (e.g., NSSDA).
- **Non-parametric based.** These methods do not require the positional error to fit an underlying parametric statistical distribution function (i.e., a non-normal distribution). The error distribution is given by the observed data17. The non-parametric approach is appropriate when the data cannot be assumed to fit a known distribution. These methods are based on percentiles or proportions, and their application is common in the case of LiDAR altimetry data of vegetated land. The PAAM based on error counting from tolerances can also be applied in this case (e.g., NMAS).

Four standards for positional accuracy assessment are presented below, providing different perspectives on estimation/control and parametric/non-parametric-based methods. In each case, a brief introduction and summary table are provided with a focus on their respective origin, comparison method, positional components on which the calculation can be performed (e.g., X, Y, and Z), existence of a standard value, a brief description of the method, and the reference to the original source.

3.8.2. American Society for Photogrammetry and Remote Sensing (ASPRS)

These standards have been developed by the Specifications and Standards Committee of the American Society for Photogrammetry and Remote Sensing (ASPRS). It is anticipated that these ASPRS standards may form the basis for revision of the U.S. National Map Accuracy Standards for both small-scale and large-scale maps. A major feature of these ASPRS standards is that they indicate accuracy at ground scale. Thus, digital spatial data of known ground-scale accuracy can be related to the appropriate map scale for graphic presentation at a recognized standard. These standards concern the definitions of spatial accuracy as they pertain to large-scale topographic maps prepared for special purposes or engineering applications. Emphasis is on the final spatial accuracies that can be derived from the map in terms most generally understood by the users.

1. **Horizontal accuracy**

Horizontal map accuracy is defined as the RMS error!, in terms of the project's planimetric survey coordinates(X,Y) for checked points as determined at full (ground) scale of the map. The RMS error is the cumulative result of all errors including those introduced by the processes of ground control surveys, map compilation and final extraction of ground dimensions from the map. The limiting RMS errors are the maximum permissible RMS errors established by this standard. These limiting RMS errors for Class 1 maps are tabulated in Table 3.8 (meters) along with typical map scales associated with the limiting errors. These limits of accuracy apply to tests made on well-defined points only.

Table: 3. 7 Show ASPRS standards for horizontal positional accuracy

(Ground X and Y in feet) for well-defined points Class-1 maps

Planimetric (X or Y) Accuracy	
Limiting RMSE, meters	Typical map scale
0.0125	1:50
0.025	1:100
0.050	1:200
0.125	1:500
0.25	1:1,000
0.50	1:2,000
1.00	1:4,00
1.25	1:10,000
2.50	1:20,000
5.00	1:20,000

2. **Vertical accuracy**

Vertical map accuracy is defined as the RMS error in evaluation in terms of the project's evaluation datum for well-defined points only. For Class 1 maps the limiting RMS error in evaluation is set by the standard at one-third the indicated contour interval for well-defined points only. Spot heights shall be shown on the map within a limiting RMS error of one-sixth of the contour interval.

3. **Lower-accuracy Maps**

Map accuracies can also be defined at lower spatial accuracy standards. Maps compiled within limiting RMS errors of twice or three times of those allowed for a Class 1 map shall be designated Class 2 or Class 3 maps respectively. A map may be compiled that complies with one class of accuracy in elevation and another in plan. Multiple accuracies on the same map are allowed provided a diagram is included which clearly relates segments of the map with the appropriate map accuracy class.

4. **Map Accuracy test**

Tests for compliance of a map sheet are optional. Testing for horizontal accuracy compliance is done by comparing the planimetric (X and Y) coordinates of well-defined ground points to the coordinates of the same points as determined by a horizontal check survey of higher accuracy. The check survey shall be designed according to the Federal Geodetic Control Committee (FGCC) [FGCC, 1984] standards and specifications to achieve standard deviations equal to or less than one-third of the "limiting RMS error" selected for the map. The distance between control points (d) used in the FGCC standard for the design of the survey shall be the horizontal ground distance across the diagonal dimension of the map sheet.

Testing for vertical accuracy compliance shall be accomplished by comparing the elevations of well-defined points as determined from the map to corresponding elevations determined by a survey of higher accuracy. For purposes of checking elevations, the map position of the ground point may be shifted in any direction by an amount equal to twice the limiting RMS error in position. The vertical check survey should be designed to produce RMS errors in elevation differences at check point locations no larger than 1/20th of the contour interval. The distance (d) between bench marks used in the FGCC standard for the design of the vertical check survey shall be the horizontal ground distance across the diagonal of the map sheet. Generally, vertical control networks based on surveys conducted according to the FGCC standards for Third Order provide adequate accuracy for conducting the vertical check survey. Discrepancies between the X, Y, or Z coordinates of the ground point, as determined from the map and by the check survey, that exceed three times the limiting RMS error shall be interpreted as blunders and will be corrected before the map is considered to meet this standard.

The same survey datum, both horizontal and vertical, must be used for both the project and the check control surveys. Although a national survey datum is preferred, a local datum is acceptable. A minimum of 20 check points shall be established throughout the area covered by the map and shall be distributed in a manner agreed upon by the contracting parties.

5. **Horizontal control network standards**

When a horizontal control is classified with a particular order and class, NGS certifies that the geodetic latitude and longitude of that control point bear a relation of specific accuracy to the coordinates of all other points in the horizontal control network. This relationship is expressed as distance accuracy, l: a. A distance accuracy is the ratio of relative positional error of a pair of control points to the horizontal separation of those points.

Table: 3. 8 Horizontal control network standards

Classification	Minimum distance accuracy
First-order	1:100,000
Second-order, class I	1:50,000
Second-order, class II	1:20,000
Third-order, class I	1:10,000
Third-order, class II	1:5,000

A distance accuracy, l: a, is computed from a minimally constrained, correctly weighted, least squares adjustment by:

$$a = \frac{d}{s}$$

Where:

a = distance accuracy denominator

s = propagated standard deviation of distance between survey point obtained from the least squares adjustment

d = distance between survey points

6. **Vertical control network standards**

When a vertical control point is classified with a particular order and class, NCS certifies that the Orthometric elevation at that point bears a relation of specific accuracy to the elevations of all other points in the vertical control network. That relation is expressed as an elevation difference accuracy b. An elevation difference accuracy is the relative elevation error between a pair of control points that is scaled by the square root of their horizontal separation traced along existing level routes.

Table: 3. 9 Vertical control network standards

Classification	Maximum elevation difference accuracy
First-order	0.5
Second-order, class I	0.7
Second-order, class II	1.0
Third-order, class I	1.3
Third-order, class II	2.0

An elevation difference accuracy, b, is computed from a minimally constrained, correctly weighted, least squares adjustment by

$$b = \frac{s}{\sqrt{d}}$$

Where:

d = approximate horizontal distance in kilometers between control point positions traced along existing level routes.

S = prorogated standard deviation of elevation difference in millimeters between survey control points obtained from a least squares adjustment. Note that the units of bare (mm)1 $\sqrt{km}$."

3.8.3. Five components of data quality

This example illustrates an important principle of geographic information systems. The value of any geographic data set depends less on its cost, and more on its fitness for a particular purpose. A critical measure of that fitness is data quality. When used in GIS analysis, a data set's quality significantly affects confidence in the results. Unknown data quality leads to tentative decisions, increased liability and loss of productivity. Decisions based on data of known quality are made with greater confidence and are more easily explained and defended. Federal standards that assist in documenting and transferring data sets recognize five important components of data quality:

- **Positional accuracy.** How closely the coordinate descriptions of features compare to their actual location.
- **Attribute accuracy.** How thoroughly and correctly the features in the data set are described.
- **Logical consistency.** The extent to which geometric problems and drafting inconsistencies exist within the data set.
- **Completeness.** The decisions that determine what is contained in the data set.
- **Lineage.** What sources are used to construct the data set and what steps are taken to process the data?

Today, use of digital GIS is replacing traditional paper maps in more and more applications. Digital geographic data sets are being generated by federal, state and local government agencies, utilities, businesses and even private citizens. Determining the positional accuracy of digital data is difficult using existing standards. A variety of factors affect the positional accuracy of digital spatial data. Error can be introduced by: digitizing methods, source material, generalization, symbol interpretation, the specifications of aerial photography, aero-triangulation technique, ground control reliability, photogrammetric characteristics, scribing precision, resolution, processing algorithms and printing limitations. Individual errors derived from any one of these sources are often small; but collectively, they can significantly affect data accuracy, impacting how the data can be appropriately used.

The NSSDA helps to overcome this obstacle by providing a method for estimating positional accuracy of geographic data, in both digital and printed form. The National Standard for Spatial Data Accuracy is one in a suite of standards dealing with the accuracy of geographic data sets and is one of the most recent standards to be issued by the Federal Geographic Data Committee.

CHAPTER IV: RESULTS AND DISCUSION

4.1. Horizontal position accuracy assessment results

For this positional accuracy assessment 22 sample points was used and analyzed. As different studies suggested that, sample selection for this study were done based on the area coverage and terrain configuration of the study area. This input data was taken from Adama land administration office. Validations of this input data were done by using EZ@SUR software. This software used to check the accuracy of data collected through GNSS technologies through comparing collected with nation data (nationally established monuments). This national data generated from Green book and from study. Based on this data the accuracy of reference fulfilled the required standards.

4.1.1. Coordinate differences between independent test points and dependent

Based on the equation (3.1 and 3.2) the difference independent test points and dependent test points was calculated and result shown on the table below:

Table: 4. 1 Coordinate difference between GPS, and the GE points

2013			2013	2023	2023	
Name	ΔE	ΔN	Quadrant	Quadrant	ΔE	ΔN
A013	19.735	26.368	1	2	5.632	-7.145
A017	-27.125	5.736	4	2	0.083	-0.08
A020	31.025	28.884	1	1	11.8089	12.5956
A024	1.749	24.962	1	3	-7.9	-1.758
A042	-2.781	7.347	4	3	-6.024	-0.021
A045	-6.067	-0.219	3	2	7.388	-7.272
A050	-9.368	-31.664	3	3	-14.201	-18.017
A068	-3.015	0.842	4	2	0.043	-0.077
A069	2.71	1.694	1	2	5.772	-5.367
A070	-2.439	-0.174	3	4	-4.277	5.353
A074	-16.341	-27.032	3	4	-4.194	13.741
A077	-4.989	1.752	4	2	0.152	-0.089
A085	2.67	1.848	1	1	2.977	4.005
A087	8.104	-0.197	2	1	3.212	1.028

A090	-24.958	-16.995	3	2	6.098	-0.089
A098	5.541	-6.552	2	2	0.034	-0.107
A102	-3.181	4.49	4	4	-6.045	6.405
A109	-1.457	-1.88	3	2	2.518	-2.492
A111	4.608	11.271	1	2	7.674	-1.318
A121	0.688	9.615	1	4	-8.06	6.7
A128	1.848	-5.653	2	2	9.611	-13.013
A150	2.547	-14.607	2	2	8.35	-6.618

Table 4.1 shows that coordinate difference between GPS and GE that include both year (2013 and 2023). As the result shows that the highest coordinate difference in year 2013 of 31.025m and the lowest of -27.125m in direction of East and 28.884 and -31.664 in North direction for highest and lowest respectively. Also in East (11.8089 and -14.201) and North (12.5956 and -18.017) Maximum and Minimum difference was observed for year 2023.

Table: 4. 2 General statistics analysis of horizontal errors between GPS and GE

	2013		2023	
Statistics	E	N	E	N
SUM	-20.496	19.836	12.3019	-13.6354
RMSE	4.3698	4.229	2.622774	2.9071
RMSEr	6.081		3.9154	
RMSE, (90%)	10.52499		6.776	
Max	31.025	28.884	11.81	13.741
Range	58.15	60.544	26.01	31.758
Min	-27.125	-31.664	-14.20	-18.017
Std. Deviation	5.98846		2.639	
Std. Error	1.27674		1.44237	

According to table 4.2 RMSEr for both direction (in Eastern and Northern), RMSEx for Eastern direction, RMSEy for Northern direction was calculated. The obtained Root Mean Square Error for twenty two control point of both GE and GPS study was 6.081 and 3.9154 in years 2013 and 2023 respectively. This result shows that there is slightly improvement of positional accuracy of GE. When compared with the finding of **(Mulu, 2019)**, in his study for national level positional accuracy of GE for this study were found well than in Addis Ababa.

Table: 4. 3 Directions and Whole Circle Bearings (WSB) of the horizontal errors/shifts

	In 2013			In 2023		
Name	Direction (°)	WCB (°)	Shift (m)	Direction (°)	WCB (°)	Shift m)
A013	36.8128	36.8128	32.94	-11.1871	168.8129	9.09923
A017	-78.822	281.2	27.725	-59.30843	120.69157	0.1153
A020	47.05	47.05	42.4	43.15366	43.15366	17.2656
A024	4.01	4.01	25.0232	47.091	227.091	8.093242
A042	-20.733	339.27	7.86	89.8002	269.8002	6.02404
A045	87.933	267.933	6.071	-45.45335	134.54665	10.36651
A050	16.4812	196.4812	33.021	38.2452	218.2452	22.9408
A068	-74.397	285.6035	3.152	-29.1808	150.8192	0.08819
A069	57.991	57.991	3.2	-47.0823	132.92	7.882
A070	85.92	265.92	2.45	-36.62455	323.37545	6.8518
A074	31.153	211.153	31.59	-16.97313	343.02687	14.3668
A077	-70.65	289.35	5.288	-59.6499	120.3501	0.176139
A085	55.312	55.312	3.247	36.62419	36.62419	4.99025
A087	-88.61	91.39	8.11	72.252739	72.252739	3.3725
A090	55.747	235.747	30.195	-89.16383	90.83617	6.1
A098	-40.221	139.779	8.581	-17.62801	162.372	0.112272
A102	-35.316	324.684	5.5026	-43.34372	316.65628	8.8072
A109	37.776	217.776	2.3785	-45.2973	134.702659	3.542653
A111	22.24	22.24	12.177	-80.2546	99.7454	7.7864
A121	4.0928	4.0928	9.64	-50.2644	309.73558	10.4811
A128	-18103	161.8971	5.95	-36.4484	143.552	16.6822
A150	-9.891	170.11	14.83	-51.6005	128.4	10.655

Table 4.4 shows results such as direction of shift, whole circle bearing, and horizontal errors of Google Earth in both 2013 and 2023 years. The errors ranged from 3.2 – 33.02m in year 2013, 0.08819 – 22.9408m in the 2023. The Standard Deviation (SD) and RMSE of the horizontal errors were derived as follows: in year 2013 (SD: 4.012m: RMSEr: 6.081m),

in year 2023 (SD: 2.6395m, RMSEr: 3.9154). As seen on the result in year 2013 the widest range of error, with vastly undulates between coordinates that represent very low fits of points, the highest shift at 33.02m at the station point of A050. As this study was done for two years (2013 and 2023) significant improvement of positional accuracy was observed.

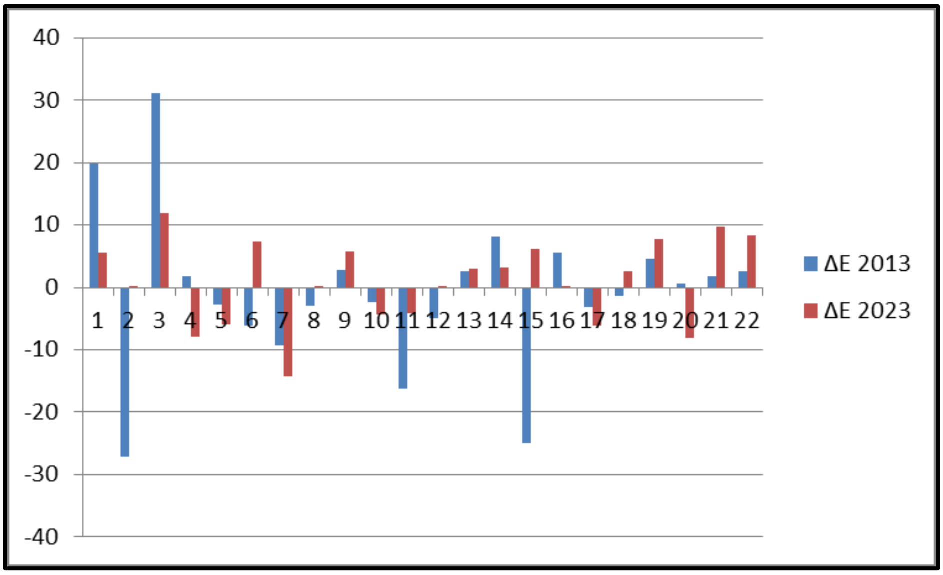


Figure: 4. 1 Coordinate changes between GPS and GE imagery in East direction

The above chart shows that the changes in Easting direction between both GPS and GE data in years of 2013 and 2023. The highest horizontal shift in Easting direction was recorded in 2013. This shift has a positive value or above the origin line.

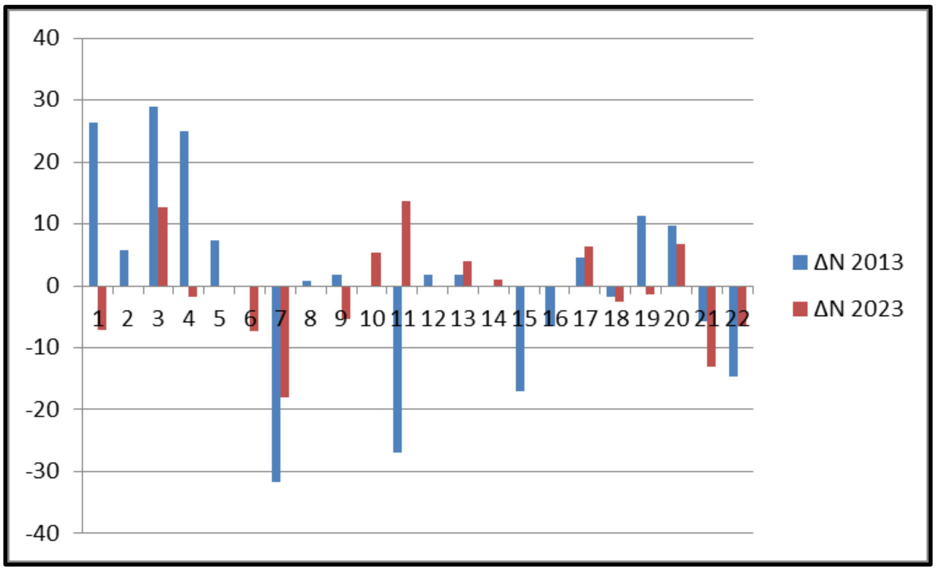


Figure: 4. 2 Coordinate changes between GPS and GE imagery in North direction

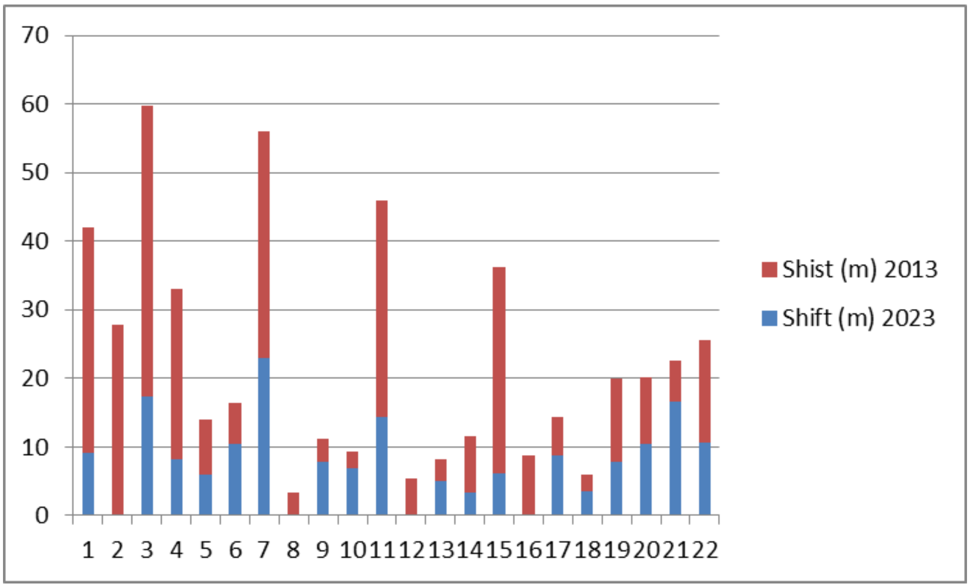


Figure: 4. 3 Horizontal errors between GPS and GE in years of 2013 and 2023

4.1.2. Horizontal accuracy assessment results TS and GE

Table: 4. 4 ΔE, ΔN, Directions and WSB of the horizontal errors/shifts of TS and GE

Name	ΔE	ΔN	Quadrant	Direction(°)	WCB (°)	Shift (m)
TP1	1.7	1.407	1	50.39	50.39	2.207
TP2	-1.101	0.196	4	-79.91	280.09	1.12
TP3	1.555	-0.027	2	-89.01	90.99	1.56
TP4	5.5	-0.249	2	-87.41	92.59	5.51
TP5	-1.042	-1.646	3	32.34	212.34	1.95
R1	2.369	-2.046	4	-49.18	310.82	3.13
R2	2.195	-0.811	4	-69.72	290.28	2.34
R3	-1.914	-3.524	3	18.72	198.72	4.01
R4	0.665	-5.541	2	-6.84	173.16	5.58
R5	-5.369	-0.838	3	81.13	261.13	5.43
GCO	3.226	1.274	1	68.45	68.45	3.46
GC	2.295	-2.605	2	-41.38	138.62	3.47
GR	2.771	-1.901	2	-55.55	124.45	3.36
BC1	-1.74	1.256	4	-54.18	305.82	2.27
BC2	1.865	-1.458	3	-51.98	231.98	2.37

Table 4.4 shows that coordinate difference, quadrant of shift, magnitude of shift, direction and Whole Circle Bearing of TS and GE. The maximum shifts between TS and GE in the SW or South West direction (shift: 5.58; direction: -6.84°). The minimum shifts were in the direction of NW or North West direction of (shift: 1.12; direction: -79.91). The horizontal accuracy between TS and GE were estimate as in East direction RMSE: 3.35001m, in North direction RMSE: 4.264m and RMSEr: 5.422m

4.2. Analysis of Vertical Accuracy

For vertical positional accuracy assessment all 142 GCPs were used as reference data which measured through GPS by Ethiopian Mapping Agency and was given to Adama city land administration office. As test data Google Earth and ALOS 3 AW3D-30m was used. After zooming each point all stations that added or imported to GE Pro were marked by using point mark tool on GE Pro. The data was saved in KML/KMH format, then by using Arc GIS 10.8 from KML to feature converted. Then ALOS 3 AW3-30m DEM imported from download file to Arc GIS and elevation data were generated. In 2015, the Advanced Land Observing Satellite (ALOS) World 3D - 30m (AW3D30) DEM was made available as an Earth topography elevation data product AW3D30 was photogrammetrically developed using optical imagery collected during the ALOS mission (Tadono, 2016). The ALOS elevation maps were produced at a spatial resolution of 5m with an accuracy of 5m (standard deviation). In 2016, JAXA released a 30m product, the AW3D30 dataset which was generated from the earlier 5m product (JAXA 2017). From the accuracy assessments by (Caglar, 2018), the AW3D30 surpassed the accuracies of SRTM and ASTER GDEM Version 2.

Table: 4. 5 (SD) and Root Mean Square Error (RMSE) of the height differences

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
CHANGE_Z	142	111.67	-64.04	47.63	-295.66	-2.0821	1.18704	14.14522	200.087
Valid N (listwise)	142								

Table 4.5 shows that descriptive statistics of height difference between GE and GPS. This table shows the descriptive statistics of the results from the basic comparison between heights from both GE and GPS. It shows that a maximum error of 47.63m, minimum error of -64.04m and mean error of -2.0821, a RMSE of 14.1984m and Standard Deviation of 14.1452m.

Generally we can say that GE data underestimate the topography of the profile by an average of -2.0821m and maximum value of 47.63m. The negative value of mean error value indicates that the majority of the errors are negative or less than zero. Therefore GE height values may be said to be negatively biased along the profile path.

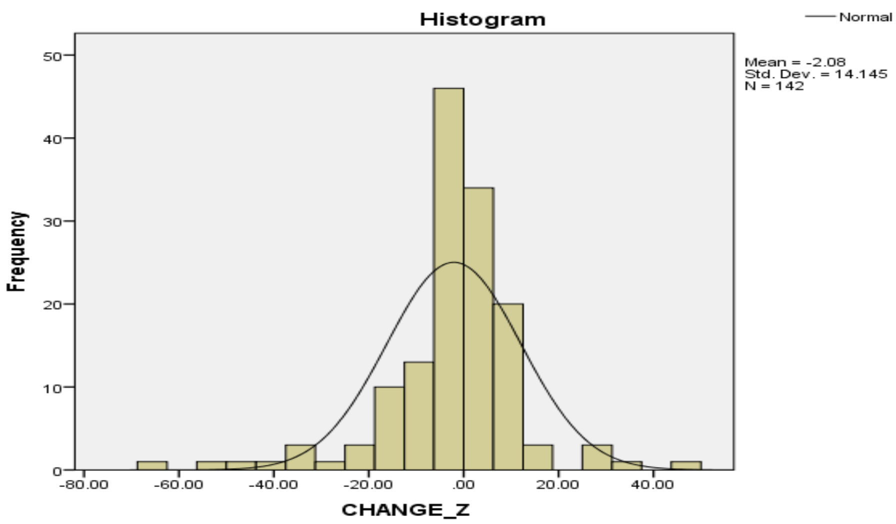


Figure: 4. 4 Histogram of residual and/or error distribution

This figure is display of the histogram of the residual error. The cursory examinations of the figure suggest that the errors follow a normal distribution. However a closer examination reveals an offset-negative skews of about -2.0821m (Mean) error from the reference line or zero point. This pattern simply suggests a likelihood of a systematic mean error of previously mentioned size in the data.

One major question in the mind of prospective users of this data (Google Earth data) is thus how much similarity exists between the two datasets and how significant is this similarity. A good way to attempt such question would be to perform a correlation analysis on both datasets.

Table: 4. 6 1.Parametric correlation analysis

Correlations

		Z_GE	Z_GPS	CHANGE_Z
Z_GE	Pearson Correlation	1	.987**	-.010
	Sig. (2-tailed)		.000	.910
	N	142	142	142
Z_GPS	Pearson Correlation	.987**	1	-.173*
	Sig. (2-tailed)	.000		.039
	N	142	142	142
CHANGE_Z	Pearson Correlation	-.010	-.173*	1
	Sig. (2-tailed)	.910	.039	
	N	142	142	142

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

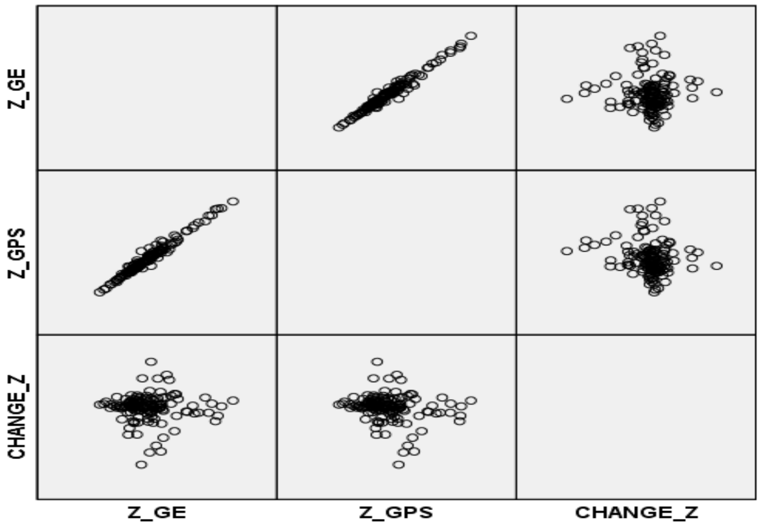


Figure: 4. 5 Scatter plot of GE verses GPS verses Residual

Table: 4. 7 Nonparametric Correlation height difference

Correlations

			Z_GE	Z_GPS	CHANGE_Z
Kendall's tau_b	Z_GE	Correlation Coefficient	1.000	.886**	-.017
		Sig. (2-tailed)	.	.000	.758
		N	142	142	142
	Z_GPS	Correlation Coefficient	.886**	1.000	-.132*
		Sig. (2-tailed)	.000	.	.020
		N	142	142	142
	CHANGE_Z	Correlation Coefficient	-.017	-.132*	1.000
		Sig. (2-tailed)	.758	.020	.
		N	142	142	142
Spearman's rho	Z_GE	Correlation Coefficient	1.000	.973**	-.028
		Sig. (2-tailed)	.	.000	.744
		N	142	142	142
	Z_GPS	Correlation Coefficient	.973**	1.000	-.201*
		Sig. (2-tailed)	.000	.	.017
		N	142	142	142
	CHANGE_Z	Correlation Coefficient	-.028	-.201*	1.000
		Sig. (2-tailed)	.744	.017	.
		N	142	142	142

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Tables 4.6, 4.7 and figure 4.2 were produced in attempting to answer the above question. Table 1 was performed on the dataset (under assumption of normality of data distribution), with Pearson’s value of 0.987 at level of 0.01 significance, reports the existence of a significant positive relationship between the two datasets (GE and GPS). This fact is further corroborated by Figure 4.4.

With an assumption that data was not normally distributed, the datasets were subjected to a two correlation analysis-Kendall’s tau and Spearman's rho; the tests, which reported respective values of 0886 and 0.973 which significant at level of 0.01, which indicate that a significant relationship between dataset.

In generally, the horizontal and vertical positional accuracy GE in years between 2013 and 2023 has significant difference. In this study we can see that positional accuracy of GE improved based statistical measures. This suggests that GE has made efforts at improving the quality of its satellite imagery over the years. Also, it shows there is a continuous enhancement in the accuracy and reliability of satellite imagery data sources which form the source of Google Earth data.

CHAPTER V: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study assessed the both horizontal and vertical positional accuracy of Google Earth imager in years between 2013 and 2023 in Adama city. The horizontal accuracy was assessed in terms of the RMSE using GPS coordinate and Google Earth imagery in years 2013 and 2023. Number of sample data used in this study meets the ASPRS accuracy standards. The horizontal accuracies were produced as follows- year 2013 (SD: 5.988, RMSE: 4.3698), in 2023 (SD: 2.639, RMSE: 3.9154) and the horizontal accuracy between TS and GE were also estimated as RMSE: 5.422m. The acquired horizontal RMSE of GE was found fit to produce a class-1 map which having scale of 1:20000 as recommended ASPRS 1990. Unlike for horizontal case, the computed RMSE for vertical positional accuracy of GE was not fit for preparing class-1 map. But, making correlations between field survey and GE elevation data can provide 95% fitness and also, subtracting the acquired RMSE for the vertical case from the original GE elevation data can provide 90% fitness for preparing class-1 map.

The main contribution of this study lies in the relevance of the findings to end-users of Google Earth images and to the broad Digital Earth community. It presents an informed perspective through quantitative analysis, on the limitations of historical archive of Google Earth's imagery in terms of the horizontal accuracy and also, the vertical accuracy of the elevation data. It is clear from literature that variations exist in map and satellite information thereby making the services rendered as error-prone. Users of these services are advised to use GE map and satellite information with caution as stated in GE terms of service. It is also important to point out that the positional accuracy of GE can be enhanced by carrying out image geometric registration on the imagery using established geodetic control points. By carrying out this enhancement, the application of GE imagery becomes extensive. The trends for GE imagery in this study have shown improvement in positional accuracy in more recent imagery. It might be advisable for users to go for the most recent imagery as the trend suggests higher accuracy in recent times. Also, users should not rely on just GE imagery but instead acquire supporting data for their analysis. It is reasonable to augment GE acquired data with other relevant and more accurate sources.

5.2. Recommendation

Because spatial accuracy can be expensive, it is important to understand accuracy standards and identify potential user positional accuracy “needs,” not “wants,” for specific applications. In our country content, digital transformation plan was launched for early 10 years. To successfully executing this plan spatial information will be the important player. In terms of Google Earth today in our country uses this technology in millions, but most of the users not recognized amount of positional errors which generated from different reasons. Also studies based on this content also minimum in national level. We need to do more. From experience I get from this study I want recommend two points for next researcher:

1. This study was done only two study period (2013 and 2023) and 10 years gap. 10 year gap is very for deep analysis of positional accuracy of GE. So I want recommend that the next researcher should minimize study years gap for good result.
2. Also I want to recommend that for next researcher to focus on thematic positional accuracy assessment. And based on the results of this study; GE imagery is recommended for class-1 map production for this study area only.

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