University of Baghdad
College of Engineering
JE
JOURNAL OF ENGINEERING

Journal of Engineering
journal homepage: www.joe.uobaghdad.edu.iq
Number 8 Volume 25 August 2019

Chemical, Petroleum and Environmental Engineering

Evaluation of the Accuracy of Digital Elevation Model Produced from Different Open Source Data

Raghad Hadi Hasan
Assistant Lecturer
Engineering College - Baghdad University
Baghdad, Iraq
raghad.surveying@gmail.com

ABSTRACT

This study aims to estimate the accuracy of digital elevation models (DEM) which are created with exploitation of open source Google Earth data and comparing with the widely available DEM datasets, Shuttle Radar Topography Mission (SRTM), version 3, and Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (ASTER GDEM), version 2. The GPS technique is used in this study to produce digital elevation raster with a high level of accuracy, as reference raster, compared to the DEM datasets. Baghdad University, Al Jadriya campus, is selected as a study area. Besides, 151 reference points were created within the study area to evaluate the results based on the values of RMS.
Furthermore, the Geographic Information System (GIS) was utilized to analyze, imagine and interpolate data in this study. The result of the statistical analysis revealed that RMSE of DEM related to the differences between the reference points and Google Earth, SRTM DEM and ASTER GDEM are 6.9, 5.5 and 4.8, respectively. What is more, a finding of this study shows convergence the level of accuracy for all open sources used in this study.
Keywords: digital elevation model (DEM), Google earth, open source data.

تقييم دقة نموذج الارتفاع الرقمي المنتج من عدة مصادر متاحة

م.م رغد هادي حسن
قسم هندسة المساحة
كلية الهندسة/جامعة بغداد

الخلاصة

الهدف من هذه الدراسة هو تقييم دقة نموذج الارتفاع الرقمي(DEM) المنتج باستغلال بيانات متاحة (Google earth) ومقارنته مع نموذج الارتفاع الرقمي المتوفر على نطاق واسع ومجاني (بعثة مكوك الفضاء المكوك الراداري (SRTM) الإصدار 3 . والنموذج العالمي للارتفاعات والانعكاس الحراري المتقدم في الفضاء (ASTER GDEM) الإصدار 2). بالاعتماد على نقاط الضبط الارضي (GPS) لإنتاج نموذج ارتفاع رقمي عالي الدقة واعتباره المرجع في هذه الدراسة. مجمع الجادرية / جامعة بغداد اختير كمنطقة دراسة لإنشاء وتحليل نموذج الارتفاع الرقمي (DEM) في هذه الدراسة. علاوة على ذلك، تم خلق 151 نقطة في داخل منطقة الدراسة (نقاط مرجعية) لتقييم دقة نموذج الارتفاع الرقمي المنتج. تم عمل وتحليل واستكمال بيانات نماذج الارتفاع الرقمي (DEMs) واخراج البيانات باستخدام نظم المعلومات الجغرافية (GIS).

---

*Corresponding author
Peer review under the responsibility of University of Baghdad.
https://doi.org/10.31026/j.eng.2019.08.07

Article received: 17/9/2018
Article accepted: 31/10/2018

أظهرت نتيجة التحليل الإحصائي أن RMSE لنموذج الارتفاع الرقمي المستخرج من Google Earth و SRTM DEM و ASTER GDEM هي 6.9 و 5.5 و 4.8 على التوالي. كما اظهرت النتائج ايضا مستوى دقة متقارب لجميع البيانات المجانية المتاحة التي تم اعتمادها في هذه الدراسة

الكلمات الرئيسية: نموذج الارتفاع الرقمي ،جوجل الارض، بيانات متاحة.

1. INTRODUCTION.

In several applications, digital elevation models represent essential parts in land use, monitoring of landslide, hydrologic analysis, and others. Several applications with higher accuracy of DEM are required despite the cost, like dam planning area and networks of the drainage channel. While, most world's areas do not have a free high-resolution DEM less than 30 meter **Srivastava and Mondal, 2012**. Various ground parameters are provided by data of freely available DEM (contour lines, slope, and terrain aspect) to be applied for geospatial analysis and 3-dimensional modeling. ASTER GDEM, 30-meter resolution and SRTM, 30-meter resolution, for the sample, is the most public freely accessible DEM.

Additionally, for DEM production various techniques were adopted with an uneven accuracy level such as photogrammetry, field survey traditionally, and laser scanner, **Suganthi and Srinivasan, 2010**. Where, for civil engineering project traditional survey techniques, total stations and leveling surveys, are utilized for high accuracy DEM generation, traditional surveying is costly compared with other techniques, **Farah, 2008**. Meanwhile, open sources Google Earth data has been studied by many investigators. Diverse corner of the scientists try to recognize substitution way of DEM, due to a mounting request of DEM with high resolution for particular applications that is not available also augmentation of the alternative pathway of DEM generation, **Faruk**, **et al., 2018**. Recently, it is known in scientific research projects Google earth among online virtual globes available has focused on increase interesting and popularity used, due to free and the easy access to global coverage with satellite imagery. Therefore, the purposes of this study are to evaluate DEM accuracy which generated based on open source data (Google earth) and compares with the freely available DEMs (SRTM and ASTER GDEM) depending on numbers of reference points (GPS) points.

1.1 Digital Elevation Models Description.

Digital elevation models (DEM) symbolize information files which have information of a specified area as the height of the earth's surface. DEM is utilized to determine the terrain's attributes, such as slope, the elevation at any point and aspect. DEM is also used to detect features on the terrain, such as drainage networks and channels, drainage basins and watersheds, peaks and pits and other landforms. What is more, DEM involves an observe array of heights for a ground positions number at spaced intervals frequently, **Balasubramanian, 2017.**

1.1.1. Digital elevation models data types and generation.

In various formats, digital elevation data are attackable. It contains Digital Surface Models (DSM), Digital Terrain Models (DTM), and Triangulated Irregular Network (TIN). The disparity between the DSM and DTM is a DSM contains all objects and represents the ground surface, while a DTM characterizes the earth surface with no objects such structure and plants, **De Sawal, 1996**. By using interpolation methods, DEM can be constructed from two major data sources. The classical ground surveying methods such as leveling, theodolite, and GPS, is the first one. While, the second source data is remote sensing surveying method such as laser scan and images of satellites, **Zahraa, 2016**. To generate DEM, the interpolation technique is coming after the data gathering step. This procedure is utilized for defining the exact position to identify point based on another point with known value (all points in generation DEM area become identified data), **Carlisle, 2002**. To imagine, achieve, integrate, and evaluate large amounts of spatial information data, GIS remains a tool commonly used. In GIS there are different obtainable interpolation methods for example ordinary Kriging (KG), spline with tension (ST) and inverse distance weighting (IDW). By comparing with the other methods, most of the studies prove that Kriging method is a suitable interpolation method for different applications, **Erdogan, 2009, Svobodová, 2011, and Arun 2013**. Consequently, ordinary Kriging (KG) is the geostatistical interpolation method which is founded on the spatial allocation of data instead of actual values.

1.2. Google Earth.

Google Earth is geographic information program and a virtual globe map that was created by Keyhole Inc. and called Earth Viewer 3D originally. Then, in 2004 by a company acquired by Google. The imagery of satellite with a resolution of about 15 meters per pixel, most of the land area is covered. This standard imagery is 30 meters multi-spectral Landsat which has pan sharpened with the 15meter panchromatic Landsat imagery. Generality, with 3 arc-second digital elevation data the Google image data are underlying. Although, for an only limited region, 1 arc second elevation data is existing too, **Arshad, et al., 2012**. To the wide spectrum of users, Google Earth exemplify a very popular source of information. Earth profiles, Ground coordinates, highway networks are somewhat program benefits among many others. The level of accuracy provided by Google Earth needs to be known by professional users such as planners, engineers. Furthermore, they need to know positions that the application provides and how far they can depend on it. The accuracy of such programs cannot be predictable to meet engineering standards at most, but such application studies with the preliminary project can benefit from it. Such as, highway designers can employ it in the route selection at the early stages when high coordinate accuracy is not a sentient issue. Google earth can make a useful guide to visualize the ground topography regardless, point's metric accuracy, during the selection of a site in the large project, **Raad, et al., 2016**. The data capturing from Google earth can be used to produce DEM in interpolation methods in the ArcMap program.

1.3. ASTER Digital Elevation Model.

Amongst the free reachable global DEMs, the ASTER GDEM Version 2 (during its release in 2011) was considered to be the highest resolution DEM, **Arefi and Reinartz, 2011**. Thus, ASTER GDEM Version2 has considerable enhancements of Version 1 which was released in 2009 in the expression of water masking, developed horizontal resolution, improved horizontal and vertical reliability, spatial coverage, and the data of new ASTER insertion to appendix the vacuums and artifacts, **NASA JPL, 2011**. Specific artifacts unmoving stay in the form of abrupt rise (humps/bumps) and fall (pits), although vastly improved, on a local scale large elevation errors can produce, **Arefi, and Reinartz, 2011.**

1.4. SRTM Digital Elevation Model.

The SRTM-30meter (SRTM V3.0, 1 arcsec) which was released in public in 2003 is an improvement to the low-resolution SRTM topographic data with 90-meter (3 arc seconds, which is 1/1200 of a degree of longitude and latitude) out the United States resolution covering regions. The new data was released in September 2014, with resolution 30-meter (or 1 arc-second), revealing by SRTM in the year 2000 the world's landforms full resolution as originally measured, **NASA JPL, 2014**. For outside the US regions, 90-meter SRTM DEMs are available were SRTM Version 3 (called "SRTM Plus") released in November 2013 by the National Aeronautics Space Administration (NASA), **NASA LP DAAC, 2013**. SRTM Version 4 released by the Consultative Group for International Agricultural Research - Consortium for Spatial Information (CGIAR - CSI) in 2008, **Jarvis, et al., 2008**. Before this release. SRTM DEMs are predicted to have linear vertical relative height error of less than 10 m, linear vertical absolute height error of less than 16 m, circular absolute geolocation error of less than 20 m, and circular relative geolocation error of less than 15 m, according to its mission objectives, **Farr, et al., 2007**, and **Kellndorfer, et al., 2004**.

2. STUDY AREA.

In this study, Baghdad University, Aljadriyah Campus was selected to achieve the aims of this study. The geographic coordinates of the study area which is in Iraq, Baghdad, Al Jadriyah is 33° 16' 21" North and 44° 22' 43" East as shown in **Fig.1**. The approximate area of the experimental district in this study is 1.1616 square kilometers.

Figure 1. Area of study, Iraq, Baghdad, Baghdad University. (GoogleEarth@2018DigitalGlobe).

3. METHODOLOGY.

3.1 Collection of GPS Elevation Data.

Differential Global Positioning System (DGPS) technique was utilized to observe (151) reference points **Fig.2** using the static method. These 151 reference points were utilized to evaluate the accuracy of the producing DEM, **Table 2**. The reference points were considered to create digital elevation raster with a high level of accuracy. Then, the DEM raster related to reference points was adopted to evaluate the accuracy of open source data (Google Earth, SRTM DEM, and ASTER GDEM) by comparing them.

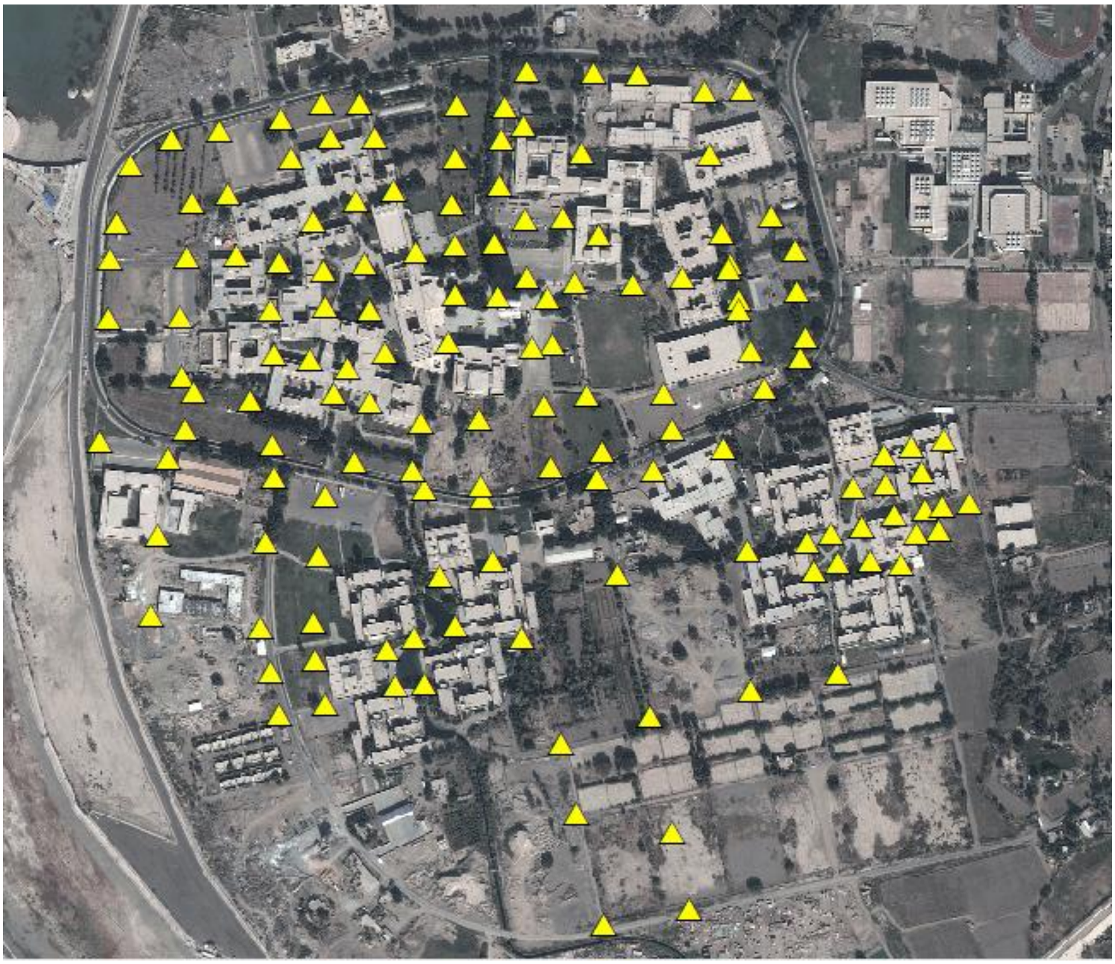

Figure 2. The distribution of GPS control points. (GoogleEarth@2018DigitalGlobe)

3.2 Collection of Google Earth Elevation Data.

Combine Path tools of Google Earth Pro software was used to draw a path; the path is loaded in TCX converter software. It is an open source software. Then it is stored in Excel sheets which was loaded to ArcGIS software (V10.3) to produce DEM based on Google Earth data of the study area, as presented in **Fig. 3**.

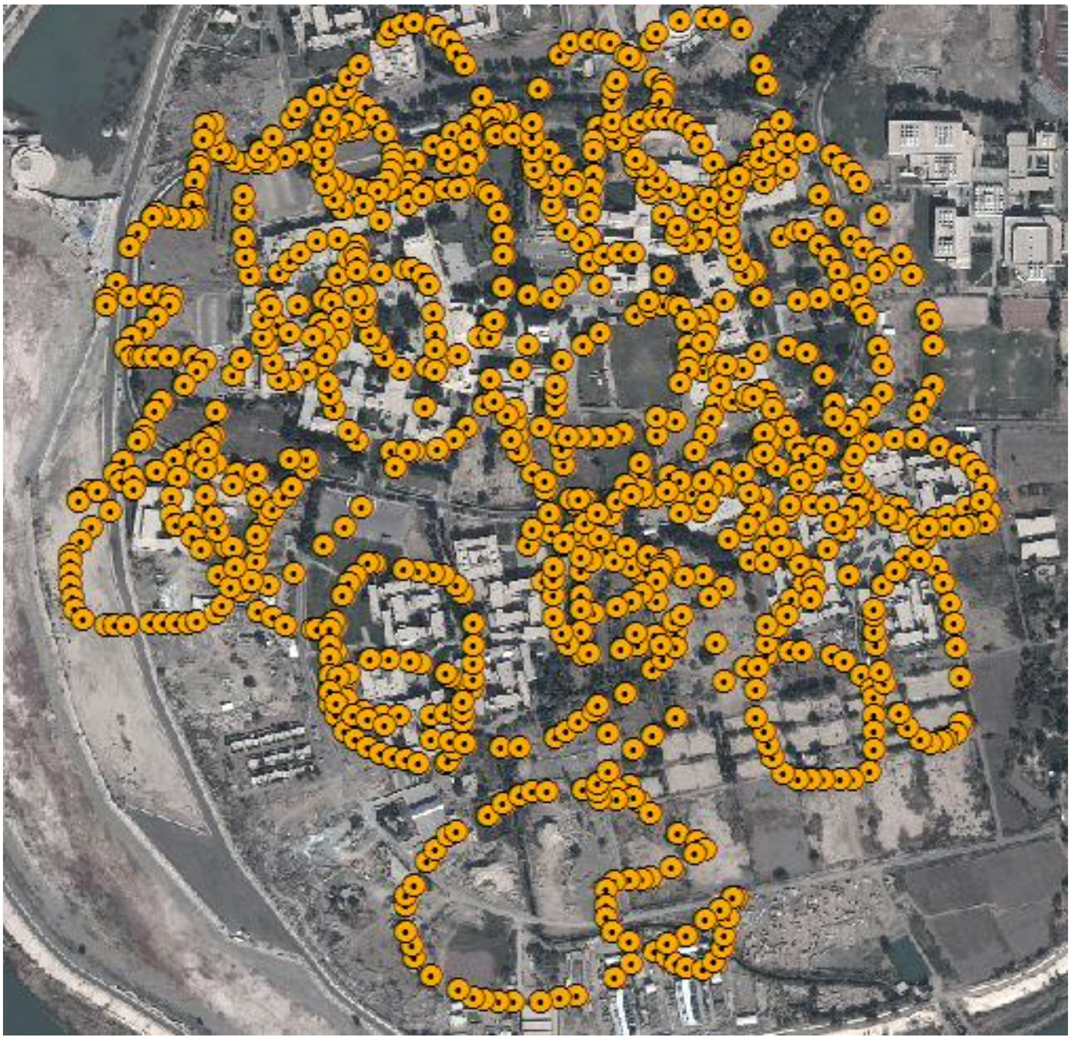

Figure 3. The allocation of Google earth path. (GoogleEarth@2018DigitalGlobe)

3.3 Data Interpolation and Accuracy Estimation.

To construct DEM and evaluate its accuracy, spatial data from Google Earth and geodetic receivers were used in this study. Geographic Information System (GIS) is utilized for GPS spatial data to imagine, interpolate and analyzing, **Bussink, 2003 and Salih, and AL-Tarif, 2012**. After collecting data, GIS tools were utilized in the interpolation method process at various stages in GIS. Essentially, excel sheets of points were added and edited for matching and extracting the elevation for same points by manual comparison between GPS points (with satellite image) and Google Earth data in the area of study. Then, by using Kriging interpolation, DEM was created for the study area. Using ordinary Kriging, this method of interpolation for spatial data was useful based on an advanced statistical method to deduce values for unobserved locations **Svobodová, and Tuček, 2009, Muhsin 2013, and Aziz, et al., 2018**. The settings used in ArcMap are:

1. Ordinary Kriging Method.
2. Spherical Semivariogram Model.
3. Variable Search Radius.
4. (12) Number of Points.

These settings are standard for all raster interpolations. Then, these DEM raster's were clipped concerning each other to create a uniform spatial area. GPS elevation point's values which significantly vary from the next point's values were added to symbolize the field data in actual terrain as it looked. Furthermore, to assess the accuracy for (SRTM) and (ASTER GDEM) and Google earth points, GPS ground control points raster were measured as reference raster as shown in **Fig.4**.

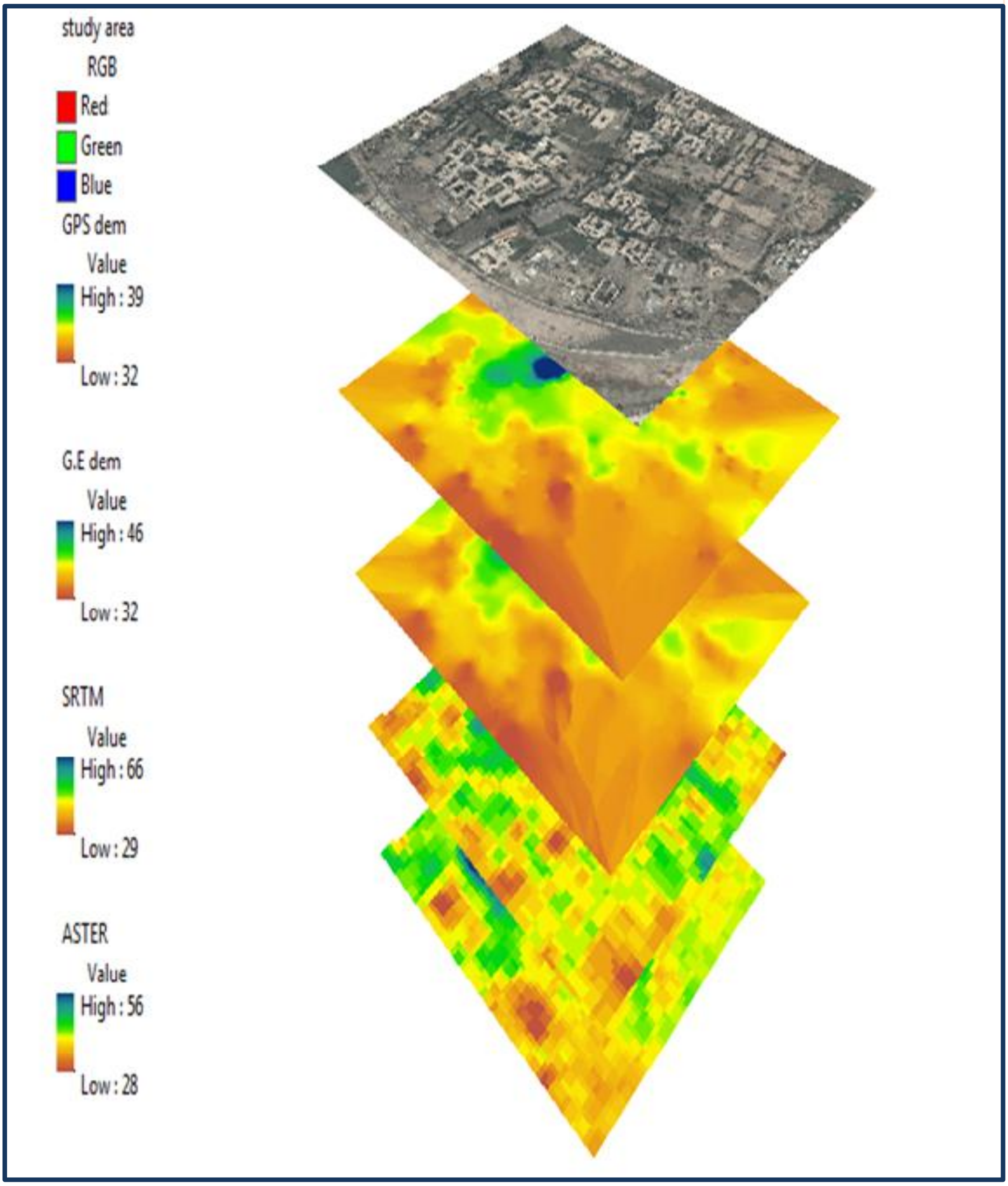

Figure 4. Produced DEM by GPS points, Google earth points, SRTM, and Aster GDEM.

Although both SRTM and Aster GDEM datasets have similar resolutions, methods and varying means were used for generating the final raster output. Errors and variations exist in the datasets due to random and systematic errors, **Guth, 2006**. Additionally, the root means square error (RMSE) used in this study is supported by several references as USGS that accepted quantifiable measure for the DEM accuracy, **Federal Geographic Data Committee, 1998**. For DEM vertical accuracy RMSE is defined by Eq.(1):

$$RMSE = \sqrt{\Sigma\ (Zi - Zt)^2/n} \quad (1)$$

where Zi refers to the interpolated DEM of a test point, Zt refers to the true elevation of a test point and n is the test points number. Predictive the model validity by RMSE quantifies, **USGS, 1998**.

4. RESULTS

Findings related to the producing the DEM for the selected open source data (Google Earth, ASTER 30 and SRTM 30) present the differences value between the reference points (151) and the created DEM raster of the study data source as shown in Table.2. Furthermore, it is clear in **Fig.5** that difference value of Google Earth is closed to SRTM30 than ASTER30. For more explanation, **Fig.5** summarized the relationships between the results of the study data. The mean and standard deviation and root mean square error (RMSE) of three different DEM in **Table.1** bring to light that Google DEM somewhat matches with SRTM 30 and shows a variation of ASTER30. Comparative profile line graph of Google DEM with ASTER30 and SRTM30 in **Fig.5** also was found that Google DEM profile differs from Aster 30 while it is similar to SRTM 30. Regarding the study findings, it possible in some cases in a large area for small scale where unavailability of sufficient data, the Google Earth elevation can be a useful another source of elevation as revealed in analysis result.

Table1. Summary of the total error and extent of elevations from Producing DEMs.

Producing DEM	Max.Elevation Difference (m)	Min.Elevation Difference (m)	Mean.Elevation Difference (m)	S.D Elevation Difference (m)	RMS elevation Difference (m)
Google earth	26.818	2.753	5	3.603	6.908
ASTER GDEM	9.968	7.701	3.381	3.479	4.851
SRTM - 30m	27.997	3.394	5.719	3.913	5.588

Table 2. Ground Control Points, Google earth, Aster and Srtm Elevations.

Points	N	E	GPS Point Elevation	Google Earth Elevation	Aster GDEM Elevation	SRTM Elevation
1	3681756.653	442080.126	37.055	41.87779999	40.74195146	46
4	3681819.211	441960.039	37.186	43.96210098	30.29532807	46
6	3681930.842	441955.21	37.563	42.15039825	44.28025782	42
10	3682052.282	442019.832	37.492	41	42.75563166	42
18	3681867.205	441687.375	38.277	40.39229965	44.52813618	39
26	3682012.79	441805.479	37.993	38.9958992	43.56595584	39
32	3681909.788	441784.371	38.321	41.79130173	46.13534686	44
33	3681791.576	441619.32	37.623	39.1053009	38.62668285	39
40	3681804.692	441798.464	39.224	41.60089874	41.82628391	43
49	3681748.875	442325.755	33.086	35.43389893	37.44466719	34
50	3681702.122	442341.468	32.021	37.55189896	39.2299916	36
62	3682028.375	442044.526	33.051	40.83100128	40.56374812	41
73	3681694.683	442122.049	32.237	40.45780182	35.82011715	38
80	3681485.758	442433.433	32.412	39.22140121	39.50260777	38
87	3681561.354	442595.559	32.317	39.98009872	33.97145222	37

89	3681526.841	442558.823	32.281	35.34659958	39.31522788	42
90	3681523.052	442529.865	32.242	33.83670044	36.70486153	44
96	3681487.845	442472.979	32.339	34.6529007	33.56811865	40
106	3681310.129	441798.136	32.334	37	38.19683491	36
123	3681409.216	441960.171	32.294	33.11729813	29.85444258	40
140	3681663.904	441987.948	31.896	37.26620102	37.04293217	41

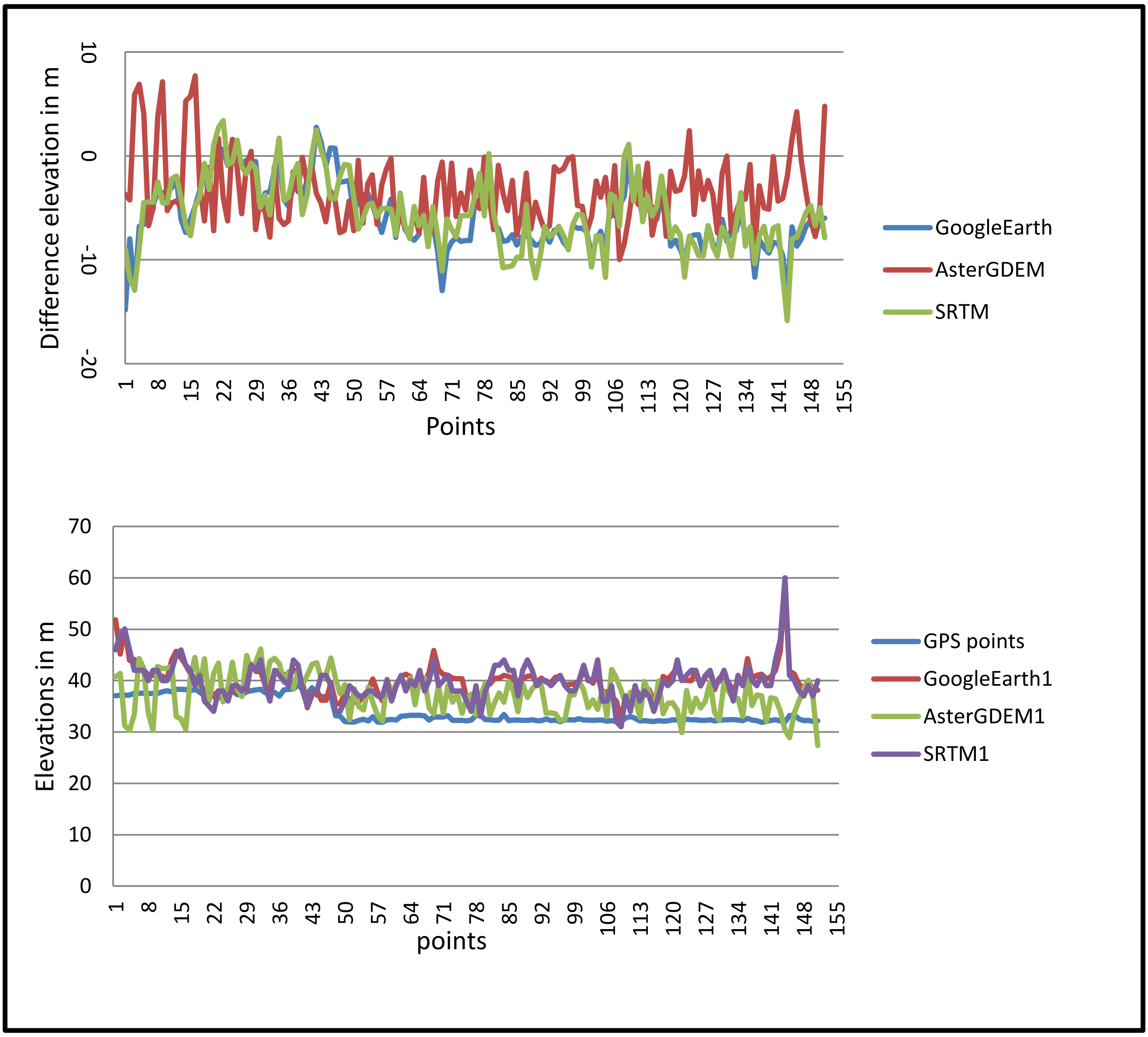

Figure 5. Rapprochement of elevation and difference elevation for the producing DEMs

5. CONCLUSIONS

It was revealed from comparative and analysis result of different DEM of the study area that data extracted from Google earth may be suitable to produce a digital elevation model in the absence of sufficient data. Meanwhile, the accuracy of digital elevation model extracted from Google earth is closer to the SRTM 30 than ASTER 30. At the same time, the ASTER DEM gives maximum accuracy level. However, the open data source chosen in this study can be used for some applications that is suitable with its accuracy level. Therefore, Google earth DEM cannot be neglected and can be relied upon in preliminary studies of the region and initial surveys if the area is flat as the study area.

REFERENCES

- Balasubramanian, A., 2017, *Digital Elevation Model (DEM) in GIS*, Technical Report, University of Mysore.

- Arefi, H., Reinartz, P., 2011, *Accuracy enhancement of ASTER global digital elevation models using ICESat data.* Remote Sensing, 3(7), pp. 1323-1343.

- Arshad, A. Muhammad M., and Muhammad B, 2012, *Quality Assessment of Digital Elevation Models in Comparison with Global Positioning Data of a Stream Profile in Dera Ismail Khan, Proceedings of the Pakistan Academy of Sciences* 49 (2): 131-138.

- Arun, P.V., 2013, *A Comparative Analysis of Different DEM Interpolation Method*, The Egyptian Journal of Remote Sensing and Space Sciences, Vol.16, PP.133-139.

- Burbank, D., Alsdorf, D., 2007, *The Shuttle Radar Topography Mission*. Review of Geophysics, 45(2).

- Bussink, C., 2003, *GIS as a Tool in Participatory Natural Resource Management: Examples from the Peruvian Ande,* Mountain research, and development, Vol.23, No.4, PP.320-323.

- Carlisle, B. H., 2002, *Digital Elevation Model Quality and Uncertainty in DEM-Based Spatial Modelling,* DISS. The University of Greenwich.

- De Sawal, R., 1996, *Digital Elevation Data and GIS projects,* In Third International Conference/Workshop on Integrating GIS and Environmental Modeling, University of California.

- Erdogan, S., 2009, *A Comparison of Interpolation Methods for Producing Digital Elevation Models at the Field Scale,* Earth Surface Processes and Landforms, Vol.34, PP.366–376.

- Farah, A., 2008, *Accuracy assessment of Digital Elevation Models using GPS*, artificial satellites, Vol.43, No.4, PP.151-161

- Faruk, H., Salma, A., and Aktarul, A. 2018, *Digital Elevation Modeling of Saint Martin Island, Bangladesh: A Method Based on Open Source Google Earth Data*,.ISSN: 2320-5407 Int. J. Adv. Res. 6(2), 379-389

- Federal Geographic Data Committee, 1998, *Geospatial Positioning Accuracy Standards*

- Guth, P. L., 2006, Geomorphometry for SRTM: Comparison to NED.

- Santillana, J. R. M. Makinano-Santillana, 2016, *Vertical Accuracy Assessment of 30-M Resolution Alos, Aster, and Srtm Global Dems Over Northeastern Mindanao, Philippines*. The International Archives of the Photogrammetry, Remote Sensing, and Spatial Information Sciences, Volume XLI-B4, 2016.

- Jarvis, A., Reuter, H.I., Nelson, A., Guevara, E., 2008, Hole-filled SRTM for the globe Version 4, available from the CGIARCSI SRTM 90m Database. http://srtm.csi.cgiar.org (28 December 2015).

- Kellndorfer, J., Walker, W., Pierce, L., Dobson, C., Fits, J.A., Hunsaker, C., Vona, J., Clutter, M., 2004, *Vegetation height estimation from shuttle radar topography mission and national elevation datasets*. Remote Sensing of Environment, 93(3), pp. 339-358.

- Muhsin, I.J., 2013, *High Spatial Resolution Digital Elevation Model (DEM) Production Using Different Interpolations Techniques,* Iraqi Journal of Physics, Vol.11, No.21, PP.116-126.

- NASA JPL, 2011, ASTER Global Digital Elevation Map Announcement. NASA Jet Propulsion Laboratory (JPL). http://asterweb.jpl.nasa.gov/gdem.asp (2015 December 28).

- NASA JPL, 2014, U.S. Releases Enhanced Shuttle Land Elevation Data. NASA Jet Propulsion Laboratory (JPL). http://www.jpl.nasa.gov/news/news.php?release=2014-321 (28 December 2015).

- NASA, LP DAAC, 2013, NASA Shuttle Radar Topography Mission (SRTM) Version 3.0 (SRTM Plus) Product Release. Land Process Distributed Active Archive Center, National Aeronautics, and space administration. https://lpdaac.usgs.gov/about/news archive/NASA shuttle radar topography mission srtm version 30 srtm plus product release (28 December 2015).online at, http://www.fgdc.gov/standards/projects/FGDC-standardsprojects/*Part3: National Standard for Spatial Data Accuracy*. Retrieved on July 5, 2008*Photogrammetric Engineering & Remote Sensing*. 72 (3) 269-277.

- N.A. Aziz, R.H. Hasan and Z.T. Abdulrazzaq., 2018, *Optimum Site Selection for Groundwater wells using Integration between GIS and Hydrogeophysical Data* Engineering and Technology Journal, Vol.36, Part A, No.6, pp.596-602, 2018.

- Raad, A., Abdulrahman, F., Hussein, H.,2016, *Evaluating the accuracy of Google Earth DEM using GPS coordinates Case study: Duhok Governorate*, The University of Duhok.

- Salih, S.A., and AL-Tarif, A.M., 2012, *Using of GIS Spatial Analyses to Study the Selected Location for Dam Reservoir on Wadi Al-Jirnaf, West of Shirqat Area, Iraq,* Journal of Geographic Information System, Vol.4, PP.117-127.

- Srivastava, V. K., and Mondal, K., 2012, March, *Evaluation of Digital Elevation Models (DEMs) generated from ASTER and SRTM Data: a Case Study of Flat Alluvium Terrain of Bakreshwar-Dubrajpur (WB), India*, in Recent Advances in Information Technology (RAIT), 2012 1st International Conference on (pp. 666-671). IEEE.

- Suganthi, S., and Srinivasan, K., 2010, *Digital Elevation Model Generation and its Application in Landslide Studies Using Information System Analysis,* Photogrammetric Engineering and Remote Sensing Vol.54, No.1593-1600.

- Svobodová, J., 2011, *Selection of Appropriate Interpolation Methods for Creation DEMs of various Types of Relief by Complex Approach to Assessment of DEMs*, GIS Ostrava

- Svobodová, J., and Tuček, P., 2009, *Creation of DEM by Kriging Method and Evaluation of the Results,* Geomorphologia Slovaca et Bohemica, Vol.9, No.1, PP.53-60.

- Zahraa Ezzulddin Hussein., 2016*, Accuracy Evaluation of Digital Elevation Model Created Using Handheld Global Positioning System Receivers*, Journal of Engineering, Vol. 22, No.6, PP.137-148.