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

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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.
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. 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. 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. 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)](image)

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.
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.
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.
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):

\[
RMSE = \sqrt{\frac{\sum (Z_i - Z_t)^2}{n}} \tag{1}
\]

where \(Z_i\) refers to the interpolated DEM of a test point, \(Z_t\) 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.

<table>
<thead>
<tr>
<th>Producing DEM</th>
<th>Max.Elevation Difference (m)</th>
<th>Min.Elevation Difference (m)</th>
<th>Mean.Elevation Difference (m)</th>
<th>S.D Elevation Difference (m)</th>
<th>RMS Elevation Difference (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google earth</td>
<td>26.818</td>
<td>2.753</td>
<td>5</td>
<td>3.603</td>
<td>6.908</td>
</tr>
<tr>
<td>ASTER GDEM</td>
<td>9.968</td>
<td>7.701</td>
<td>3.381</td>
<td>3.479</td>
<td>4.851</td>
</tr>
<tr>
<td>SRTM - 30m</td>
<td>27.997</td>
<td>3.394</td>
<td>5.719</td>
<td>3.913</td>
<td>5.588</td>
</tr>
</tbody>
</table>
### Table 2. Ground Control Points, Google earth, Aster and Srtm Elevations.

<table>
<thead>
<tr>
<th>Points</th>
<th>N</th>
<th>E</th>
<th>GPS Point Elevation</th>
<th>Google Earth Elevation</th>
<th>Aster GDEM Elevation</th>
<th>SRTM Elevation</th>
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<tbody>
<tr>
<td>1</td>
<td>3681756.653</td>
<td>442080.126</td>
<td>37.055</td>
<td>41.87779999</td>
<td>40.74195146</td>
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<tr>
<td>4</td>
<td>3681819.211</td>
<td>441960.039</td>
<td>37.186</td>
<td>43.96210098</td>
<td>30.29532807</td>
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<tr>
<td>6</td>
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<td>441955.21</td>
<td>37.563</td>
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<td>44.28025782</td>
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<td>442019.832</td>
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<td>38.9958992</td>
<td>43.56595584</td>
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<tr>
<td>87</td>
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<td>442595.559</td>
<td>32.317</td>
<td>39.98009872</td>
<td>33.97145222</td>
<td>37</td>
</tr>
</tbody>
</table>
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.

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