Assessing the Quality of Freely Available Digital Elevation Models (DEMs) over Wasit Region, Iraq

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Abstract

The accuracy of Digital Elevation Models (DEMs) is often varying and is non-uniform within each dataset. DEMs is essential for Earth science and hydrological applications. It can be generated using photogrammetry, interferometry, ground and laser surveying, and other techniques. Some of the DEMs are freely available (open-source) products such as ASTER GDEM 30m,SRTM DEM 30m, Merge GHT 30m and ALOS PALSAR12.5m.In this research the quality of open source DEMs has been evaluated based on topographic maps and field surveying data. The DEMs have been created and compared using a set of tools within ArcGIS software. The comparison between the surfaces (interpolation surfaces)that were derived from the topographic map points (spot points) with the free surfaces DEM (ASTER30, SRTM30, Merge30 and ALOS PALSAR12.5)showed that the Merge DEM with RMSE of 2.303m is the best and SRTM is the second with RMSE of 2.452m, ASTER RMSE of 2.965m and ALOS PALSAR of 3.643m.

Introduction:

A Digital Elevation Model (DEM) originally referred to a digital model of a portion of earth's surface (Burrough and McDonnell, 1998). A DEM contains either a two-dimensional array of numbers representing the spatial distribution of elevations on a given number regular grid, an irregular point network set of x, y, and z coordinates, or strings of contour stored in the form of x, y coordinate pairs along each line of contour elevation (Walker and Willgoose, 1999). While there are some drawbacks nowadays, traditional grid DEMs are the most common because of their computational efficiency.

For many purposes, DEMs are useful and are an essential precondition for many applications (Kim and Kang, 2001; Vadon, 2003). These are particularly useful in regions where accurate topographical maps are not available. DEMs have also been found to be useful in many fields of study such as geomorphometry because they relate primarily to surface functions such as landslides that can be represented directly from a DEM (Hengl and Evans, 2009)(Forkuor & Maathuis, 2012).

Taylor et al., 2015 investigated the new global digital elevation model GDEM v2. The accuracy of those two computerized as late discharged rise models DEM was measured using ICESat / GLAS (Ice, Cloud and Country Elevation Satellite / Geo-Science Laser Altimeter System). The study area was the South American Altiplano watershed. The GDEM v2 was most accurate worldwide than SRTM v4, and it about 8.8 meters downward.

The vertical and horizontal accuracy using point's comparison is the focus of this research. This DEM based on the results of GDEM v2 and a current MERGE DEM, reflecting the TDPS topography. However, the users should know its trial concentrated on a comparison point-to-point and did not take into account neighboring pixel relations. The effect would be incorrect topographic if the elevation pixel were more significant than or less than the pixels surrounding, whereas data of reality was the other way around. Hydrological applications based on calculation of medium slope that include calculations of global topography. Local corrections may still be possible, however, and errors can result in poor hydrological network extraction and inadequate boundaries of water.

Moreover, Imrani et al., 2016 evaluated open-source DEMs (ASTER and SRTM) with a reference DEM generated through contour map interpolation and ground control points for their derived attributes. The DEMs are closely connected to their accuracy regarding the quality of derived attributes, such as pistes and drainage networks. However, open-source DEMs show partially low precision in high altitude terrain and forest areas, the quality of the datasets in large-scale studies is sufficient. The current analysis tested the vertical accuracy of the ASTER GDEM Version 2 and SRTM height model.Two reference data were used for the validation: surveying control points and high DEM posting from the contour chart.

Interestingly, compared to the surveying control points and DEMs derived from the contour map, the accuracy of ASTER and SRTM heights is higher than the mission specifications. ASTER surface, in comparison with SRTM, provides better accuracy. Although SRTM, ASTER, and DEM have different representations of surface objects, the results showed that the data have a high level of vertical accuracy in smooth, hilly terrain with an average error of below 1 meter. The study suggested that elevation models may be useful for a small regional sample, which only has a small impact on the model results on the inaccuracies of the SRTM and ASTER data.

This study aims to assess the accuracy of(open- source) DEMs based on topographic maps and field surveying data in Wasit region, Iraq. The DEMs have been created and compared using a set of tools within ArcGIS software. Field observations have been achieved to make geo-reference, geometric correction of topographical maps and to determine the accuracy of DEMs.

Methodology:

2.1 The study area:

The study area was chosen in Al-Aziziya city. It is one of the districts of Wasit Governorate in Iraq, which is located about 85 km south of Baghdad and about 90 km north of Wasit. The geographic location of the study area has been illustrated in table (1). It covers about (15x 12 km^2) between Al-Aziziya and Zubaidiyah city toward the center of the Wasit. The elevations of the study area are ranging between 19 to 34m above mean sea level. Figure 1 shows the main properties of the study area.

Table 1 Study area location.

point	Lat.	Long.
Upper left	32.901525°	45.100760°
Down left	32.801446°	45.100705°
Upper right	32.901526°	45.250727°
Down right	32.801541°	45.250720°

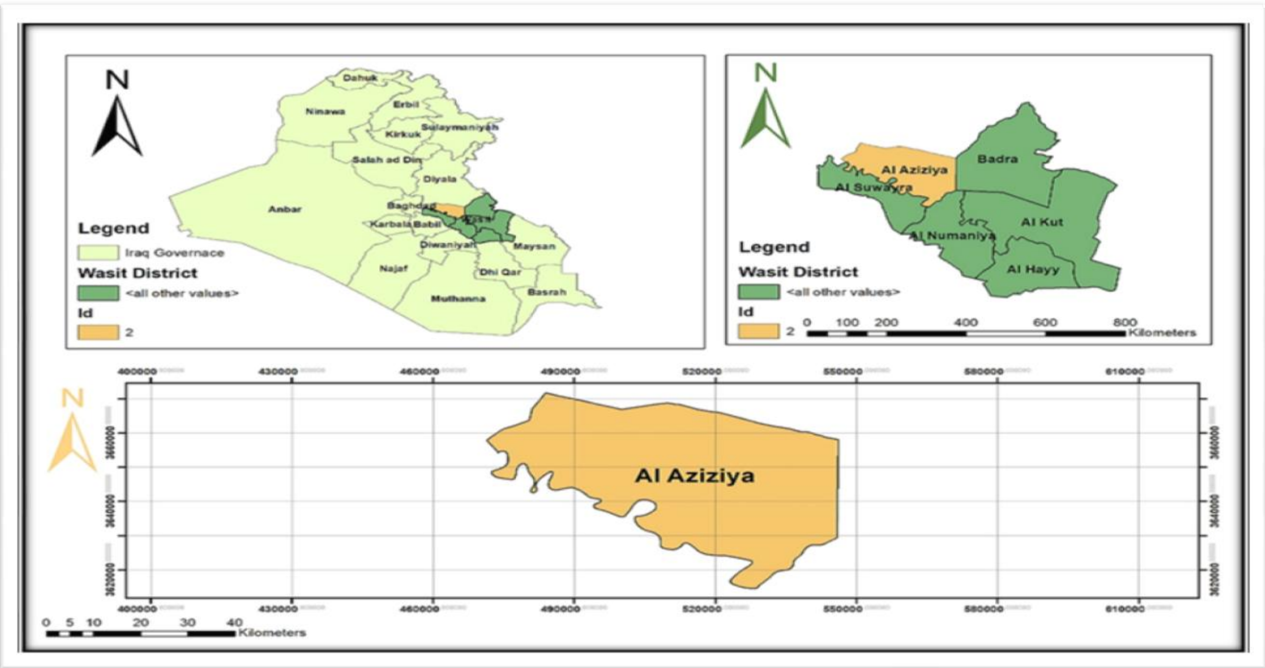

Figure 1 Al-Aziziya District (The study area).

2.2 Data Preparation and Processing

Initially, the topographical maps of the Aziziyah region were obtained from the General Authority for Surveying in Iraq with scale of 1: 10,000. Six maps were used covering the study area extending over an area (15 * 12 km^2).These paper maps were scanned to convert into digital format (raster).

In this study, field observations were carried out using the Topcon Hipper II GPS. in March 2020 as shown in table 2. These data have been used to determine the accuracy of the elevations extracted from the topographic maps. Field measurements were also used for comparing evaluating the accuracy of free DEM types.

Table 2 The field serveying observations.

Point	ID	Easting (m)	Northing (m)	EGM08_elev. (m)	Polish_elev. (m)
1	AS1- ST.	521748.181	3639287.523	22.566	22.416
2	AS2- ST.	521738.363	3639274.292	22.569	22.419
3	AS2R- ST.	521717.883	3639291.042	22.534	22.384
4	CH1- ST.	509986.982	3637177.144	25.775	25.625
5	CH2- ST.	511105.413	3637330.095	25.420	25.270
6	CH4- ST.	514851.905	3638136.876	23.743	23.593
7	CH12- ST.	512829.270	3632022.135	24.173	24.023
8	CH13- ST.	513388.285	3630856.169	24.016	23.866
9	CH14- ST.	515115.625	3638523.390	24.407	24.257
10	CH20- ST.	515308.606	3631456.223	23.550	23.400
11	CH24- ST.	515996.012	3631504.299	22.311	22.161
12	CP1- ST.	512994.057	3632247.341	24.315	24.165
13	EL1- ST.	516818.701	3636728.213	22.066	21.916
14	H1-ST.	509584.486	3637161.724	26.861	26.711
15	H2- ST.	512857.625	3637737.092	25.909	25.759
16	H6- ST.	517518.074	3636590.547	24.206	24.056
17	H7- ST.	515930.678	3630949.422	23.058	22.908

The horizontal datum of the topographic paper maps was (Iraq nahrwandatum1967) which is converted to WGS1984 by using ground control points. Vertical datum was (Polish system / UTM Zone 38N).

DEMs data datum is the World Geodetic System 1984 (WGS84) ellipsoid on the horizontal directions, and Earth Geopotential Model 1996 (EGM96) geoid in the vertical direction.

The spot points on topographic maps have been digitized to obtain 3073 points as illustrated in table 3. According to field surveying conducted by the Iraqi state commission, the old Iraqi elevation system (GTS) is higher than the polish system with about 15 cm. Hence, this difference has been subtracted from the elevations of all digitized points to obtain an elevation in the Polish system.

Z_Polish sys.(topo.sheet)	account	percentage
>=19,>20m	4	0.13%
>=20,>21m	12	0.39%
>=21,>22m	112	3.64%
>=22,>23m	574	18.68%
>=23,>24m	1036	33.71%
>=24,>25m	954	31.04%
>=25,>26m	268	8.72%
>=26,>27m	49	1.59%
>=27,>28m	55	1.79%
>=28,>29m	4	0.13%
>=29,>30m	3	0.10%
>=30,>31m	0	0.00%
>=31,>32m	1	0.03%
>=32,>33m	0	0.00%
>=33,>34m	0	0.00%
>=34,>35m	1	0.03%
	3073	100.00%

Table 3 illustrates the accounts of points that are digitized with their percentage.

Then, the Kriging method, one of the methods of Raster Interpretation, was applied to establish the continuous surface representing the reference DEM.

After that, it became possible to extract the elevation values (Z) from the continuous surfaces (DEM) created from topographic maps (Kriging 30*30m) and (Kriging 12.5*12.5m). A set of tools within ArcMap softwarewas used to convert these continuous surfaces to grid of center pixel points and accordingly, an elevation of 172,692 points was extracted from the surface (30 * 30 m) and 992085 points from the surface (12.5 * 12.5 m) to be dealt. Then the elevations of theses surfaces were compared with free DEMs (ASTER GDEM 30m, SRTM DEM 30m, Merge GHT 30m and ALOS PALSAR 12.5m).

2.3 The accuracy of Z value:

In this study, statistical indices have been adopted for the evaluation, validation and comparison of all surfaces. The difference between the elevations of reference (field surveying data) and tested data was calculated for each point. The elevation of points obtained from these DEMs are compared with the reference DEM in order to determine the accuracy of the particular DEM. Minimum and maximum errors are also estimated.The mean error (ME) magnitude, standard deviation (STD) and root mean square error (RMSE) were then determined, as follows:

$ABS(DZ) = \left| Z_{free\ DEM} - Z_{refDEM} \right|$ ……………………………………………..…(1)

Minimumabsolute error = min $(|Z_{free\ DEM} - Z_{ref\ DEM}|)$ ……………………….……(2)

Maximum absolute error = max $(|Z_{free\ DEM} - Z_{ref\ DEM}|)$……………………………(3)

Mean absolute error $= \frac{\sum_{i=1}^{n} ABS\,(DZ)i}{n}$……………………….....(4)(Jing et al., 2014)

$STD_{err} = \sqrt{\frac{\sum_{i=1}^{n}(ABS\,(DZ) - ME)^2}{n-1}}$……………………………….(5)(Jing et al., 2014)

$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(ABS\,(DZ))^2}{n-1}}$…………………………………….(6)(Jing et al., 2014)

Where:

ABS(DZ) = absolute elevation error.

$Z_{free\ DEM}$= elevation extracted from DEMs raster layer.

$Z_{ref.\ DEM}$ = elevation extracted from reference DEM layer that made from topographic maps.

n = total number of points.

STD_{error} = Standard Deviation.

RMSE = Root Mean Square Error.

3. Results analysis:

Part one: it involved evaluation the accuracy of topographic maps with field surveying points and make a comparison with the points extracted from free DEMs.The intension was determining the elevation differences between all data sources and field surveying data, as shown in table 4.

Table 4 the value of (Zm) from all surface.

Point	ID	Z_GPS m	_toposhee m	_Kriging3 m	_Kriging12. m	_ASTER3 m	_SRTM3(m	_Merge3(m	_ALOS12.5 m
1	AS1−ST.	22.416	22.348	22.221	22.221	23.869	24.565	24.565	19.000
2	AS2−ST.	22.419	22.349	22.217	22.220	23.499	23.807	24.129	18.042
3	AS2R−ST.	22.384	22.332	22.242	22.237	24.502	23.502	24.000	18.000
4	CH1 -ST.	25.625	25.398	25.301	25.292	24.971	26.047	25.000	21.648
5	CH2 -ST.	25.270	25.125	24.708	24.705	23.323	26.323	26.000	21.000
6	CH4 -ST.	23.593	23.907	23.833	23.844	20.050	25.721	26.571	20.000
7	CH12−ST.	24.023	24.172	24.141	24.144	24.600	27.000	26.954	21.000
8	CH13−ST.	23.866	23.358	23.896	23.892	18.937	27.984	27.969	22.000
9	CH14 -ST.	24.257	24.254	24.533	24.532	24.978	26.779	26.536	22.000
10	CH20−ST.	23.400	23.460	23.358	23.351	22.072	25.464	26.000	20.000
11	CH24−ST.	22.161	22.306	22.476	22.446	20.674	25.309	24.309	19.023
12	CP1 -ST.	24.165	24.123	24.037	24.037	27.101	25.973	25.000	20.000
13	EL1 -ST.	21.916	22.008	23.819	23.817	19.250	26.190	26.000	20.229
14	H1−ST.	26.711	26.881	25.410	25.412	26.518	30.212	28.411	25.000
15	H2 -ST.	25.759	25.430	24.711	24.708	21.613	27.158	26.750	22.000
16	H6−ST	24.056	24.340	24.584	24.575	21.055	25.959	25.985	20.161
17	H7−ST.	22.908	22.834	22.718	22.709	25.606	25.290	25.507	19.000

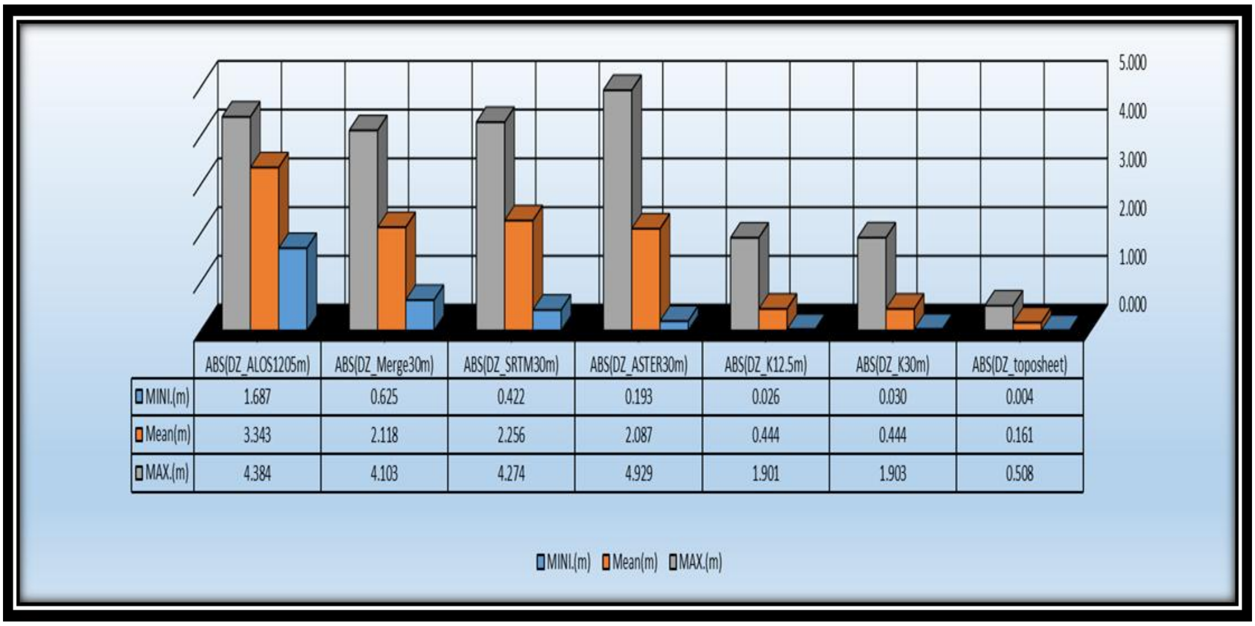

Figure 2 MAX. And MINI. value of ABS (DZ).

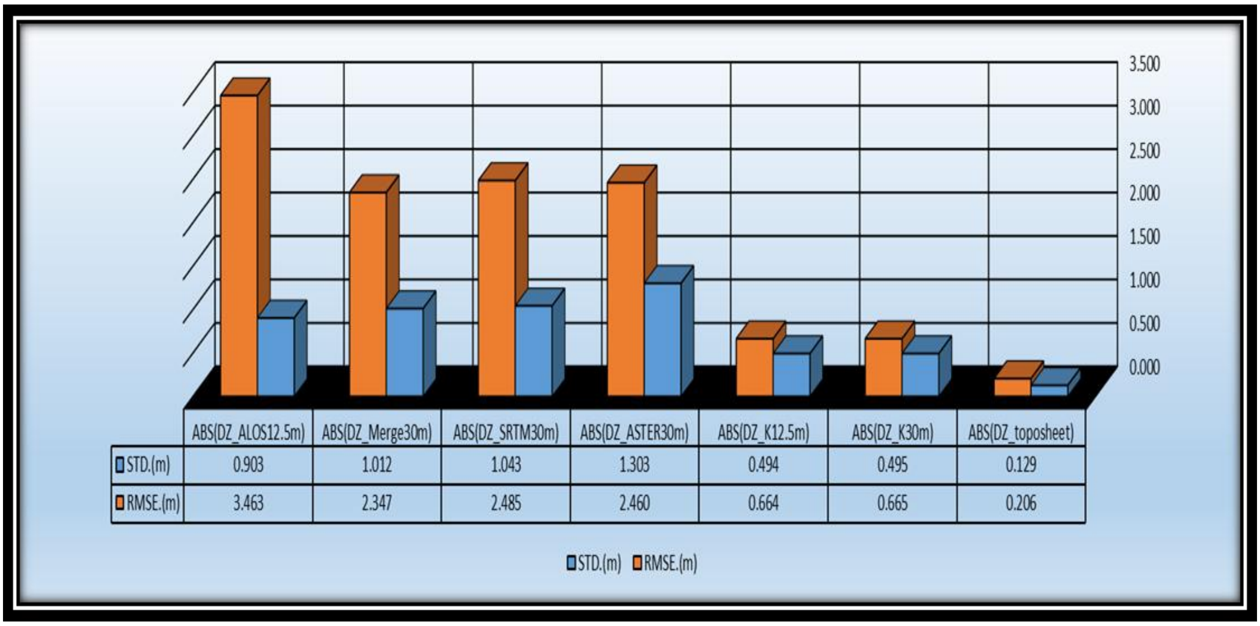

Figure 3 Show the value of Standard Deviation and Root Mean Square Error for ABS (DZ).

Figure 2showed that the max. ABS(DZ) = 0.508 for topographic mapswhich mean it is more close to the reality ground.

Concerning the RMSE, figure 3 found that the lowest RMSE value was in topographic maps data (0.206m) followed by the surfaces kriging (12.5,30)m with results equal to (0.665,0.664) m respectively.Followed byMerge (2.347m), ASTR (2.460m), SRTM (2.485m) and AlOS PLSAR (3.463m).

Part two: it included the comparison of the digital elevation models (DEM) derived from the topographical map (Krigng30m, Kriging12.5m) with all open source DEM. The results of the comparison can be seen in figures (4 to 7).

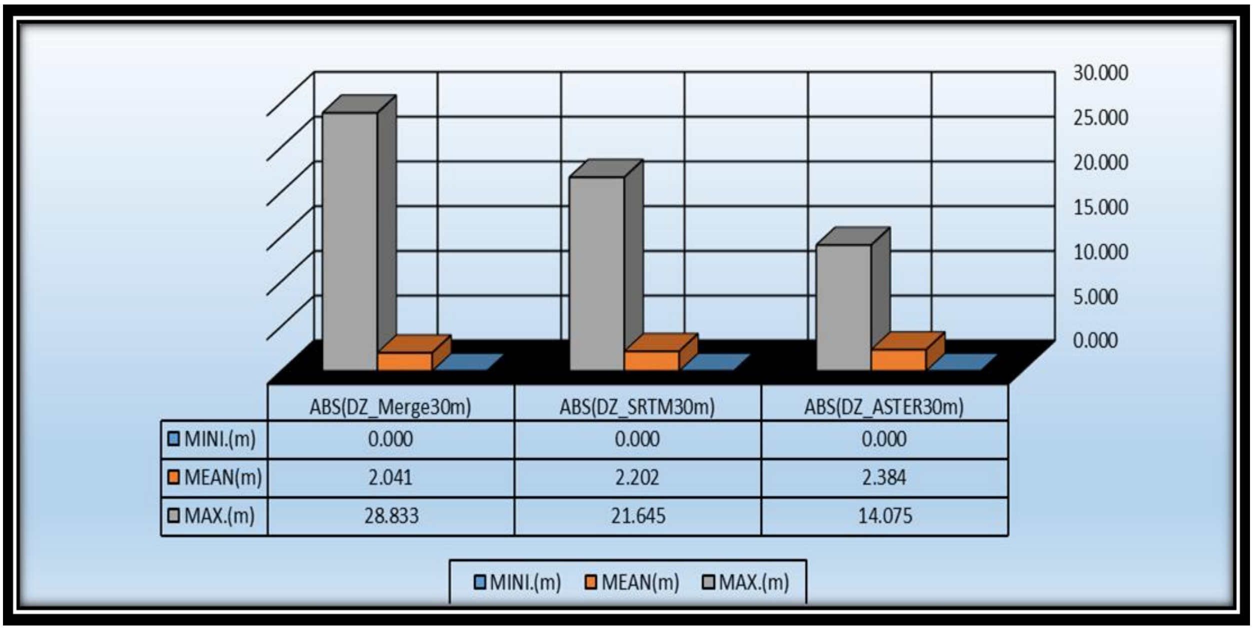

Figure 4 Max. And Min. (Z) of ASTER30m, SRTM30m and Merge30m DEM.

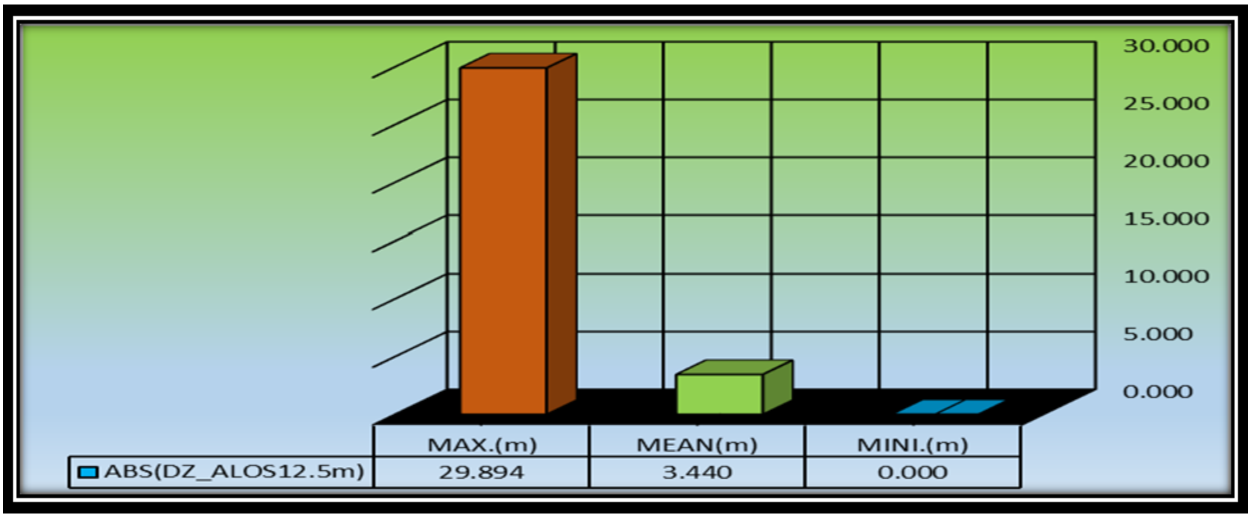

Figure 5 Max. And Min. (Z) of ALOS PALSAR12.5m.

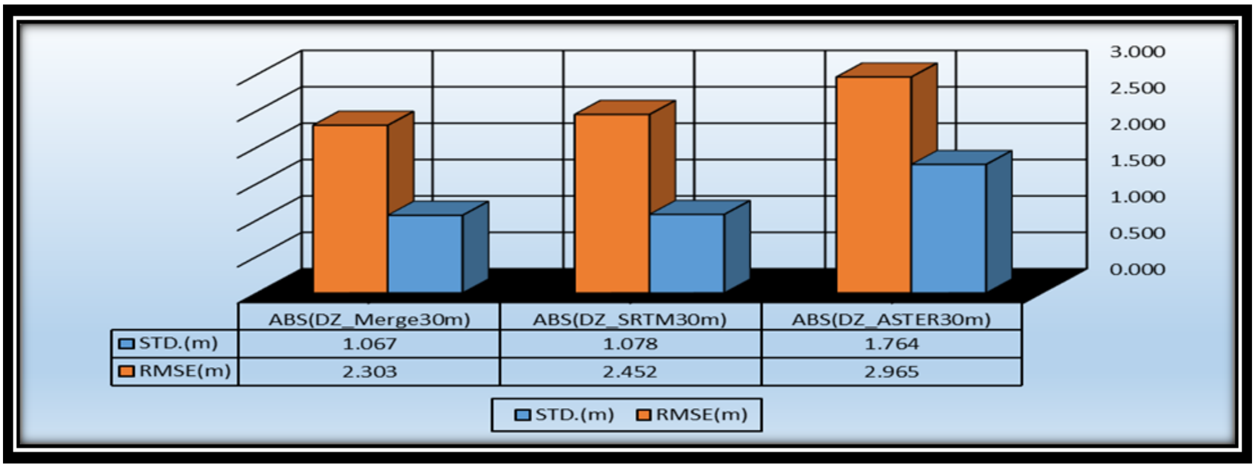

Figure 6 The Statical indices of the ABS (DZ) OF ASTER30m, SRTM30m and Merge30m DEM.

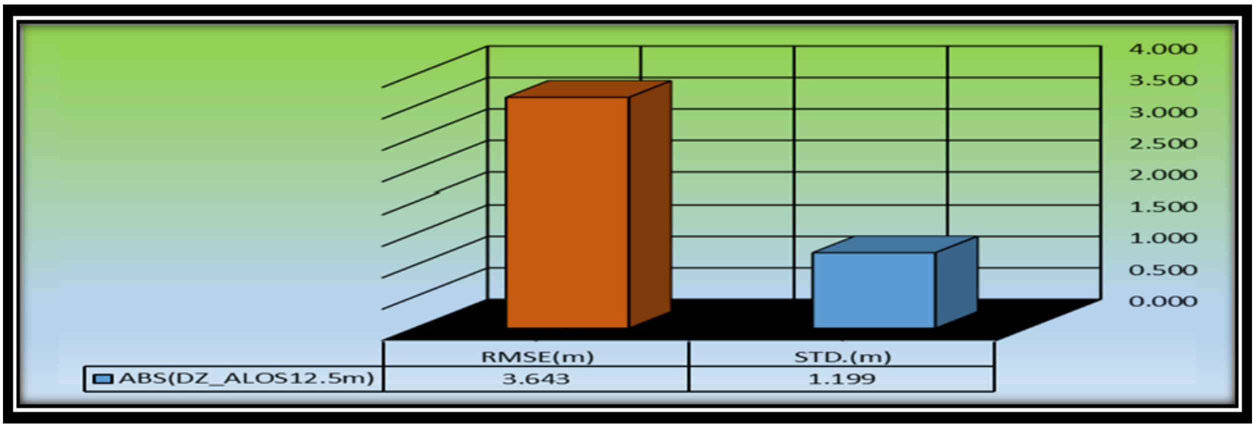

Figure 7The Statical indices of the ABS (DZ) of ALOS PALSAR12.5m DEM.

This part showed the Merge30 DEM has the lowest value with RMSE = 2.303m and STD. = 1.067 m followed by SRTM with RMSE = 2.452 m and STD. = 1.078 m.

4. Conclusions:

In this research, the field surveying data and topographical maps from the General Authority for the Survey in Iraq were used as a reference for comparing and evaluating the accuracy of open-source DEMs(ASTER30m, SRTM30m, Merge30m and ALOS PALSAR12.5m).

By converting the reference surfaces to points (pixel centre), the elevations of these points were extracted from all four surfaces (ASTER30m, SRTM30m, Merge30m and ALOS PALSAR12.5m). Then it was compared by extracting the absolute difference between the elevation of these points and finding the values of the statistical indicators for the absolute differences (DZ).

The comparison procedure was divided into two phases: the first stage was to compare all surfaces (reference and free DEM) with field observing points.It was followed by a comparison of the four free surfaces with the topographic maps.

It was concluded that the latest NASA release (Merge30m) was somewhat more accurate according to the value of RMSE of 2.303m, followed by SRTM30m with close results RMSE of 2.452m, then ASTER30m of 2.965m and finally ALOS PALSAR12.5m of 3.643m.

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