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Comparison of Different DEM Generation Methods based on Open Source Datasets

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ABSTRACT

Digital Elevation Model (DEM) is one of the developed techniques for relief representation. The definition of a DEM construction is the modeling technique of earth surface from existing data. DEM plays a role as one of the fundamental information requirement that has been generally utilized in GIS data structures. The main aim of this research is to present a methodology for assessing DEMs generation methods. The DEMs data will be extracted from open source data e.g. Google Earth. The tested data will be compared with data produced from formal institutions such as General Directorate of Surveying. The study area has been chosen in south of Iraq (Al-Gharraf / Dhi Qar governorate. The methods of DEMs creation are kriging, IDW (inverse distance weight), spline, and natural neighbor. This research used different software for processing and analysis such as ArcGIS 10.2, TCX and Civil 3D. Two- sample t-test has been adopted to investigate the mean of elevation differences between compared datasets. The results showed that the spline is the best method that can be used to build DEM in this study area.

Keywords: DEM, kriging, IDW, spline, natural neighbor, Google Earth.

المقارنة بين طرق إنتاج النموذج التضاريسي الرقمي بالاعتماد على البيانات المجانية

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الخلاصة

يُعرف نموذج الارتفاعات الرقمية (DEM) على انه أحد التقنيات المتطورة لتمثيل تضاريس سطح الأرض. يلعب DEM دورًا مهما في تهيئة متطلبات المعلومات الأساسية التي يتم استخدامها بشكل عام في هياكل بيانات نظم

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المعلومات الجغرافية. يستخدم DEM لنمذجة البيانات الموجودة على سطح الأرض (على سبيل المثال بيانات الارتفاع) وعرض قيم الارتفاع لكل المنطقة المغطاة. يهدف هذا البحث إلى تقديم منهجية لتقييم طرق أنتاج نماذج الارتفاع الرقمية . سيتم استخدام البيانات من المصادر المجانية مثل Google Earth لإنتاج نموذج الارتفاع الرقمي والتي ستقارن مع البيانات التي تنتجها المؤسسات الرسمية مثل الهيئة العامة للمساحة . منطقة الدراسة التي تم اختيارها تقع جنوب العراق في محافظة ذي قار (منطقة الغراف). هناك عدة طرق لإنتاج النموذج الارتفاع الرقمي و منها kriging و IDW و spline و natural neighbor. في هذا البحث تم استخدام برامج مختلفة مثل TCX converter, ArcGIS 10.2 وبرنامج Civil 3D لمعالجة و تحليل وعرض البيانات. فيما يخص تقييم و مقارنة النتائج فقد تم استخدام أساليب إحصائية مختلفة أهمها two sample t-test لمقارنة معدل الارتفاعات بين مصدري البيانات. أظهرت النتائج أن spline هي أفضل طريقة لإنتاج النموذج التضاريسي في منطقة الغراف.

الكلمات الرئيسية: DEM, kriging, IDW, spline, natural neighbor, Google Earth

1. INTRODUCTION

The DEMs represent a common method in creating topographic maps, orthophotos and civilian engineering ventures in addition to other various engineering applications. Recently several software programs were developed and utilized to create DEM from various sources for example field surveying, scanned topographic maps and stereo photos that displayed from air or space. The main purpose of the construction of a DEM is to represent surface elevation, which is an essential aspect of spatial analysis **(Susetyo, 2016).**

The quality of DEM is reliant on the variety of interrelated factors such as composing the techniques for information obtained, the nature data sources, and the techniques utilized in creating the DEMs. In each of the various methods of DEM creation, accuracy of generated DEM also relies on interpolation techniques **(Borrough, et al., 2005).** They are generally produced through digitizing existing topographical maps. While, each DEMs obtained from digitized contour maps are an estimation of an approximated true universal (**Erdogan, 2009**). The digital elevation model resolution, or pixel size, decides its detail. In this way, decisions on the DEM resolution must rely on the proposed application **(Sindayihebura et al., 2006)**. DEM has been utilized as an instrument to illustrate the Earth's surface for numerous purposes, like hydrological modeling exactness agriculture, civilian engineering, big-scale mapping and geological engineering **(Shingare et al. , 2013)**. A DEM may be a numeric data file which consists of elevation of the topography over the particular region, sometimes in a fastened network period above a surface of the Earth **(Davidović, et al., 2016).** Several sources may be utilized to obtain DEM data, such as Global Positioning System (GPS), Radar, geographic data, lidar, field measurements, existing topographic maps, and photogrammetry techniques.

Many previous studies compared and analyzed different DEMs creation methods. For example, (**Susetyo, 2016)** investigated three DEM interpolation techniques, namely TIN, IDW, and kriging. The DEM created utilizing different interpolation methods generated in a different level of accuracy for each method. The aim of this study was to choose the preferable assessment for DEM build when similar data is utilized for whole methods. The findings suggested that two parameters can be utilized to measure the precision of generated DEM, who are the ME (Mean Error) and the RMSE (Root Mean Square Error). The consequences from the DEM creation showed that TIN reliable makes a higher ME and RMSE compared with different techniques, which indicated that this method has a comparatively low precision when utilized to build a DEM. These results provided further support for the hypothesis that IDW and kriging have the same accuracy for creating DEM.

(Alidoost and Samadzadegan, 2013) compared ASTER GDEM ver2 and SRTM DEM with more than 800 reference ground control points (GCPs) and also with a local elevation model in Iran. This paper utilized vertical accuracy, systematic error (bias) and outliers for DEMs utilizing both the usual (Mean Error, Root Mean Square Error, Standard Deviation) and the robust (Median, Normalized Median Absolute Deviation, Sample Quantiles) descriptors for examining DEM's characteristics. The visual assessment tools were utilized to clarify the quality of DEMs, such as normalized histograms and Q-Q plots. The outcomes of the research confirmed that there is a negative elevation bias of approximately 5 meters of GDEM ver2. The measured NMAD and RMSE for elevation differences of GDEM-GCPs were 3.2 m and 7.1 m, respectively, while these values for SRTM and GCPs were 9.0 m and 4.4 m. Also, in comparison with the local DEM, GDEM ver2 exhibits the RMSE of about 6.7 m, a little higher than the RMSE of SRTM (5.1 m). The results of height difference classification and other statistical analysis of GDEM ver2-local DEM and SRTM-local DEM reveal that SRTM is a little more accurate than GDEM ver2.

(Wijeratne and Manawadu, 2016) showed validation of spatial interpolation techniques in GIS. It is valuable to change point information into surface or grid information. Interpolation is a technique used to predict the unknown place values utilizing known location values. The IDW, spline and Kringing methods are the most general methods obtainable in GIS. This study concentrated on assessing the suitability of different interpolation methods in term of their accuracy for creating rainfall surface depends on the major meteorological observatories in Sri Lanka. Five various interpolation techniques (IDW, Kriging, Natural Neighbour, Spline and Trend) were investigated using ArcGIS 10.1. The rainfall information for ten years from 2003 to 2013 for twenty-two metrological observatories in Sri Lanka were examined. For defining the accuracy on the interpolation, F test was used for this purpose. The results of this study showed that the best method is spline.

(Ikechukwu, at el., 2017) presented a comparative analysis for IDW, spline, natural neighbor and Kriging methods. Spline gives a more exact model and results for the elevation got specifically from field review. In this study, spline gave a lot of exact models and result for the elevation information acquired from field survey that was not homogenously randomized and not normalized. The root mean square error, is most minimal for Spline and most for Kriging for each prediction and validation. The DEM data analyzed is Google Earth data as a source of open-source datasets.

2. METHODS OF DEM PRODUCTION

2.1 Kriging Interpolation Method

Kriging was established on an idea of irregular functions with surface or volume suggested single attention for the random function with a recognized spatial covariance **(Mitas, and Mitasova, 2005)**. This method can be within the analysis of point information is that the derivation and plotting yet description concerning the semi-variance contrasts between the adjoining values **(Hengl, 2009)**. Regionalized variable theory accept as the spatial variety about each variable may be illustrated the accompanying four portions:

1) A structural part is having a steady average or pattern.
2) A regionalized variable, who is the random yet spatially linked component.
3) A random, however, the spatially unrelated noise or residual component.
4) Mathematically, for a random variable z at x, and can be compensated as follows

$$Z(x) = m(X) + \varepsilon'(X) + \varepsilon'' \quad (1)$$

Where:

m(x): a structural function modeling a structural component,

ε'(X): the spatially auto- associated stochastic residual out of m(X) (the regionalized variable),

ε": random noise which is generally spread with an average of zero and a variance σ^2(**Burrough, P.A., and McDonnell, R.A., 1998**).

The Kriging interpolation techniques can be divided into ordinary kriging, simple Kriging, and Universal Kriging.

2.2 Natural neighbor Method

The essential equation utilized in the natural neighbor method is **(Boissonnat and Cazals, 2002)**:

:

$$f(x) = \sum_{i=1}^{k} w_i(x)\, a_i \quad (2)$$ **(Ledoux et al. ,2005)**

where :

f(x) is the interpolated function esteem at the position x and a scalar value.

Weights utilized in the natural neighbor interpolation method depend on the meaning of local coordinates. Local coordinates known as the "neighborliness" or measure of effect any scatter point can own calculated value at the interpolation point. This neighborliness is completely reliant on the region of the impact of the Thiessen polygons of the around scatter points.

To determine the local coordinates for interpolation of the point, Pn, the region of all Thiessen polygons in the network need to be defined. Tentatively enter Pn into the triangulated irregular network (TIN) reasons the TIN and the relating Thiessen network to variation, bringing about new Thiessen regions for polygons in the neighborhood of Pn **(Rajab Khalil, 2004)**. Every neighbor inside a proven distance from the interpolation position x are considered, and the weight of every neighbor is inversely proportional about distance to x. Natural neighbor interpolation is not influenced by these problems because the selection of the neighbors depends on the making of the information **(Rajab Khalil, 2004)**. This interpolation method algorithm utilizes a weighted mean of the neighboring observations, while the weights are commensurate with the "borrowed area". The Natural Neighbor technique does not any longer anticipate contours behind the convex hull of the information positions (for example the outline of the Thiessen polygons) **(Yang, et al., 2004)**.

2.3 Inverse Distance Weighting (IDW) Method

The IDW technique expects the value at an obscure site is often approximated as a weighted mean of the values at points inside a specific cut-off distance or from obtained numerous of the nearest points (commonly 10 to 30). This technique essentially relies upon estimating the height of the unknown point through computing the distances from this point to the other known points. IDW may be a technique which is simple to utilize and comfortably accessible; it considerably does not product the local shape implicit through information and creates from it local highly at the points **(Mitas, and Mitasova, 2005)**. Some alteration has offered to ascend to a category of the multivariate mixed inverse distance weighting surfaces and volumes **(Watson, 1992)**. The presumption for inverse distance weighting method is such measured points nearer for unknown point can be higher similar to than those who are more away in their values **(Ikechukwu, et al., 2017)**.

The major factor impacting the precision of Inverse Distance Weighting is the value of the power parameter. The weights reduce in the distance increments, particularly when the value of the power parameter increments, therefore neighboring samples have a heavier weight and own a lot of impact on the estimation, and the result spatial interpolation is local **(Isaaks and Srivastava, 1989)**. The parameter of power and the neighborhood size is random **(Webster and Oliver, 2001)**. The most prominent option of p is 2 and the consequence technique is usually referred to as inverse square distance or inverse distance squared (IDS). The power parameter may additionally be picked depending on the blunder measuring (such as minimum that represents absolute error), coming about the ideal inverse distance weighting **(Collins and Bolstad, 1996)**. The softness for the predestined surface differs directly with a power parameter, and it is discovered that the estimated outcomes come to be less satisfactory when p is one and two contrast with when p is 4 **(Ripley, et al., 1981)**. Inverse distance weighting is indicated to as “moving average” when p is zero **(Brus, et al., 1996)**, “linear interpolation” when p is 1 and “weighted moving average” when p is not equivalent to one **(Burrough, and McDonnell, 1998)**. One of the qualities of IDW is the creation of "bull's-eyes" about the location of observations inside the gridded region. The smoothing parameter decreases the "bull's-eye" impact through smoothing the interpolated grid.

$$Z(X,Y) = \frac{\sum_{i=1}^{n}\left[\frac{Z_i}{d_i^p}\right]}{\sum_{i=1}^{n}\left[\frac{1}{d_i^p}\right]} \tag{3}$$

$$Z(X,Y) = \sum \lambda_{i\bullet} Z_i \xrightarrow{with} \sum \lambda_i = 1 \tag{4}$$

d_i: is the planimetric distance between the reference point and also the ith interpolation point (Robinson and et al., 2006).

$$d_i = \sqrt{(X_i - X)^2 + (Y_i - Y)^2} \tag{5}$$

$z(x,y)$: is the anticipated value at the unsampled position x,y.

n: represents the number of measured sample points inside the area-specific for x,y.

Z_i: represents the observed value at location i.

λ: are the distance-dependent weights related to every sample point.

d_i: is shown the distance between the prediction position x,y, and the measured location i.

p: is the power parameter that characterizes the rate of decrease of the weight as the distance gets bigger.

n = 1, 2, 3,4,5……………...

2.4 Spline Method

These models utilize mathematical functions for linking the tested information points. These models production ceaseless elevation and grade surfaces, whereas restricting the curvature about surface generated for the minimum **(Ikechukwu, et al., 2017)**. A main advantage of the spline is that it can create completely accurate and visually appealing surfaces based on only a little sample point **(Wu, et al., 2016)**. Spline functions may be the mathematical equivalents over the resilient ruler cartographers utilized, referred to as spline, to suit soft curves by many steady points. The spline is a piecewise polynomial encompass many parts, every of that is a ride on a little number about points so that everything about sections signs up at the points indicated for as breakpoints. This has the benefit of assimilation local modifications, if there are variations about information in the point, and is favorite to an easy polynomial interpolation as a result of a lot of parameters may be characterized, containing the amount of smoothing. The spline is usually fitted utilizing small order polynomials (i.e. second or third order) obliged to sign up. Spline might be 2D (such as while smoothing a contour line) or 3D (in the modeling a surface). The smoothing spline function and supposes the existence for the estimation error in the information such wants to remain smoothed locally **(Burrough and McDonnell, 1998)**. Between the numerous versions and modulation of spline method, the more broadly utilized method is the thin-plate splines **(Hutchinson, 1995)**, and in addition the regularized spline with pressure and the smoothing **(Mitas, and Mitasova, 2005)**.

3. CASE STUDY

The study area is located in Al Gharaf / Dhi Qar city southern Iraq, which covers about ($111km^2$). The surveying data for this area were accomplished by General Directorate of Surveying. The topography of this area is almost flat as the maximum elevation is 14.549 m and the minimum elevation is 6.170 m about the mean sea level (MSL). **Table 1** illustrates the coordinates of the boundary of the study area. **Fig. 1** shows the study area taken from Al Gharaf city.

Table 1. The coordinates of the points surrounding the study area.

Pt.	Easting(m)	Northing(m)
1	600572.148	3510263.970
2	601818.107	3509573.055
3	601142.684	3506173.349
4	601421.744	3501976.239
5	595087.137	3501333.773
6	586612.387	3500878.522
7	586168.732	3502373.540
8	594691.797	3507096.379

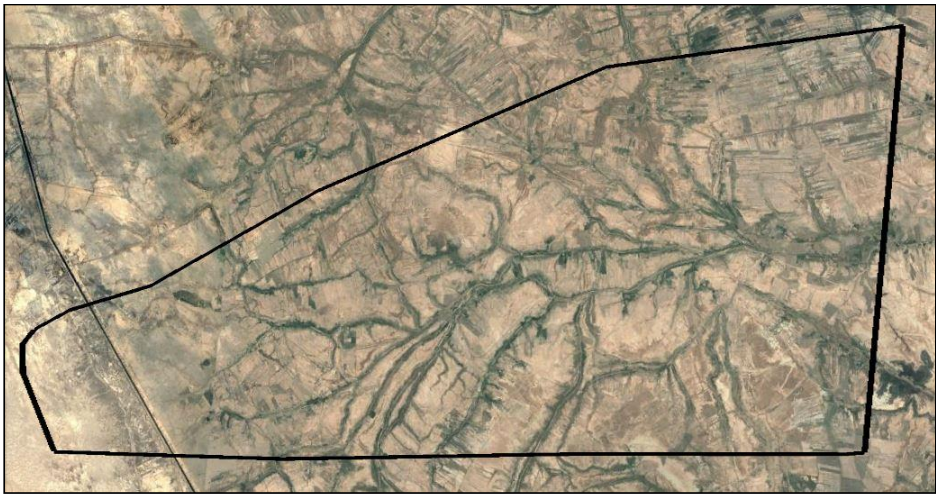


Figure 1. The study area.

4. DATA SOURCES

4.1 Data from General Directorate of Surveying

In order to assess the DEMs accuracy of Google Earth data, high accuracy datasets should be used as reference datasets. In this research, formal data was obtained from the General Directorate of Surveying. The reference data of the study area (Al-Gharaf) was collected using field surveying. The number of surveying points is 6545points. The coordinates of the same points were extracted from Google earth to compare between DEM of Google earth and reference data.

4.2 Google Earth Pro

Google Earth Pro is a fake globe, map, and land data. This program was also named Earth Viewer three dimensions, and this was made through Keyhole Inc, gained during Google in 2004. It maps the Earth by means of the superimposition of images got from aerial photography, Geographic Information System 3D globe, and satellite imagery. The program interface is shown in **Fig. 2 (Mohammed et al., 2013)**.

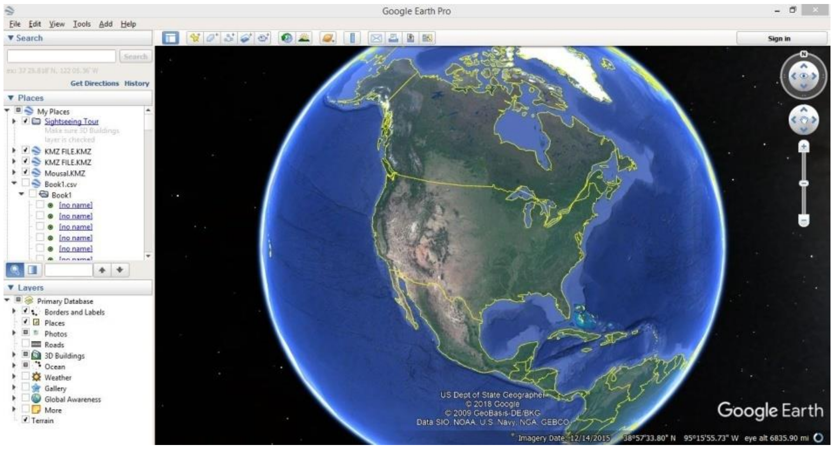


Figure 2. Google Earth software interface.

Google Earth Pro gives an open-source, simple to be reachable and cost-free image information which helps map interest society. More than just giving locational data, Google Earth enables clients to include their own substance, for example, photographs or portrayals of zones or points of interest **(Mohammed, et al., 2013)**.

The download and installation are free on each PC system – PC, Linux, and Mac. By satellite images, maps, territory, 3D structures and different locational information **(Mohammed, et al., 2013).**

The interior coordinate system of this program is geographic coordinates which include latitude and longitude on the World Geodetic System of 1984 (WGS84) datum, i.e., a similar datum which is utilized through Global Positioning System. The larger portion about high-resolution images within Google Earth Pro maps is the Digital Globe Quickbird that is around 65cm pan-sharpened (65 cm panchromatic at nadir and 2.62 m multispectral at nadir). Google is working to change this fundamental imagery with 2.5 m SPOT Image imagery and numerous higher resolution data. Several population focuses are as well secured by using airplane imagery (orthophotography) with many pixels for each meter.

Google Earth Pro document format is that the Keyhole Markup Language (KML) who is a file format for modeling and saving geographic characteristics for example lines, points, polygons, images, and models for show in this program, Google maps or different purposes. Google Earth may utilize KML to participate sites and data with different users of those purposes. For its coordinate system, KML utilizes three dimensions geographical coordinates; longitude, latitude and altitude, in a specific arrangement, the longitude, latitude constituents could be characterized in the WGS84 (World Geodetic System of 1984). The altitude that is the vertical part can be measured from the WGS84 EGM96 Geoid vertical datum **(Mohammed et al. , 2013)**.

5. METHODOLOGY

The methodology of this study included studying previous research related to the subject of this research, and collect the reference data from a reliable government institution for the study area. Then extracting open-source data (Google Earth Pro) for study area using TCX converter software, it is achieved through several steps. After preparing data for both exporters, ArcGIS10.2 software was used for producing DEMs by four methods (Kriging method, IDW method, natural neighbor method, and spline method) for study area. To compare the exporters for each method, AutoCAD Civil 3D software was used to compare the elevation of each cell (after interpolation) in the reference source to the corresponding cell in the Google Earth. The last stage was comparing the DEMs accuracy applying statistical analysis such as t-test and graphical analysis to predict the accuracy and error magnitudes within DEMs that generated from Google Earth data and reference data (General Directorate of Surveying), **Fig. (3)** shows the methodology of the research.

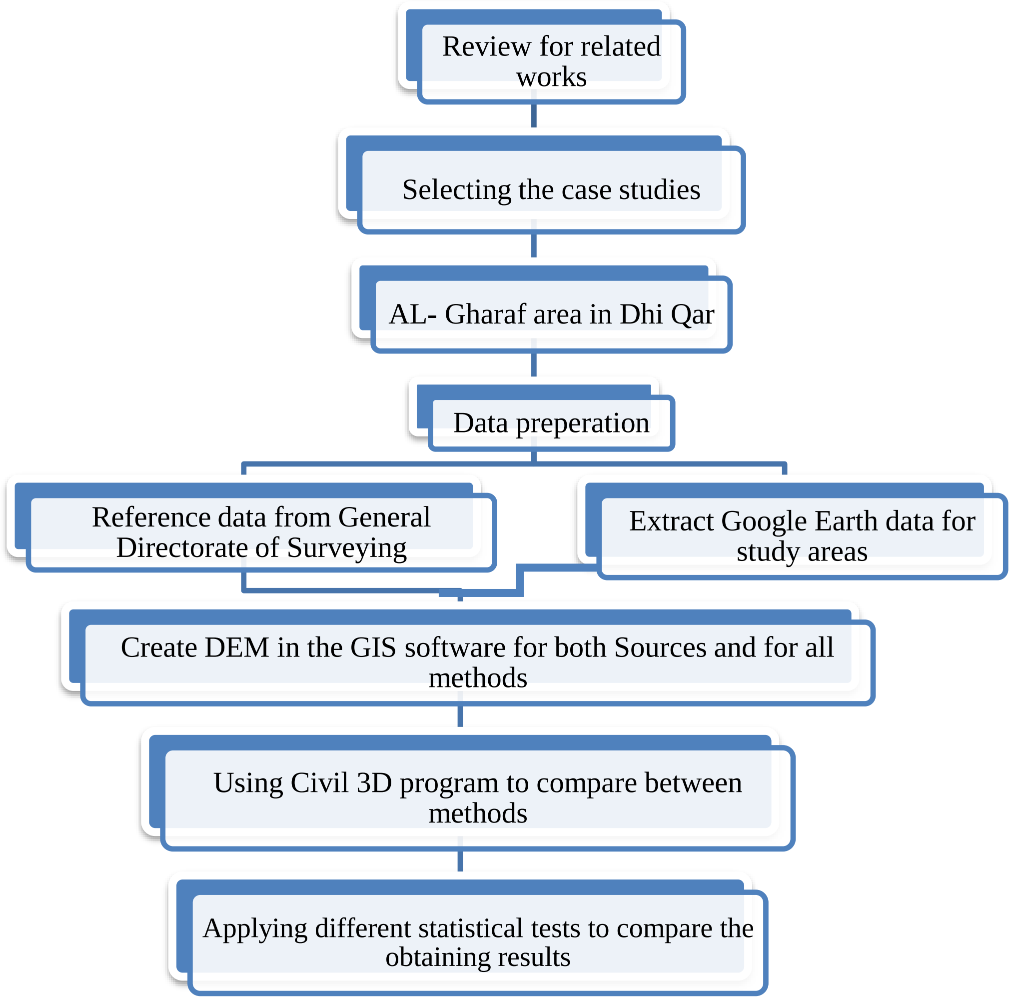


Figure 3. The methodology of the research.

6. ELEVATION DATA COLLECTION

In order to convert the KML file into Excell file, TCX Converter software has been used. This software only works with the Internet. To extract data, the following steps should be followed: From the main window of the software, the OPEN FILE is chosen, then the KML file is selected. The latitude, longitude will show but altitudes are equal to zero, so Track Modify should be chosen then Update Altitude the software does processing, and after seconds the altitude values will appear. The data can be exported by choosing Export and save CSV file, and the storage location is determined as shown in **Fig.(4)**. The resulting coordinates are in the geographic system, therefore, they should be converted to the UTM system by GIS software.

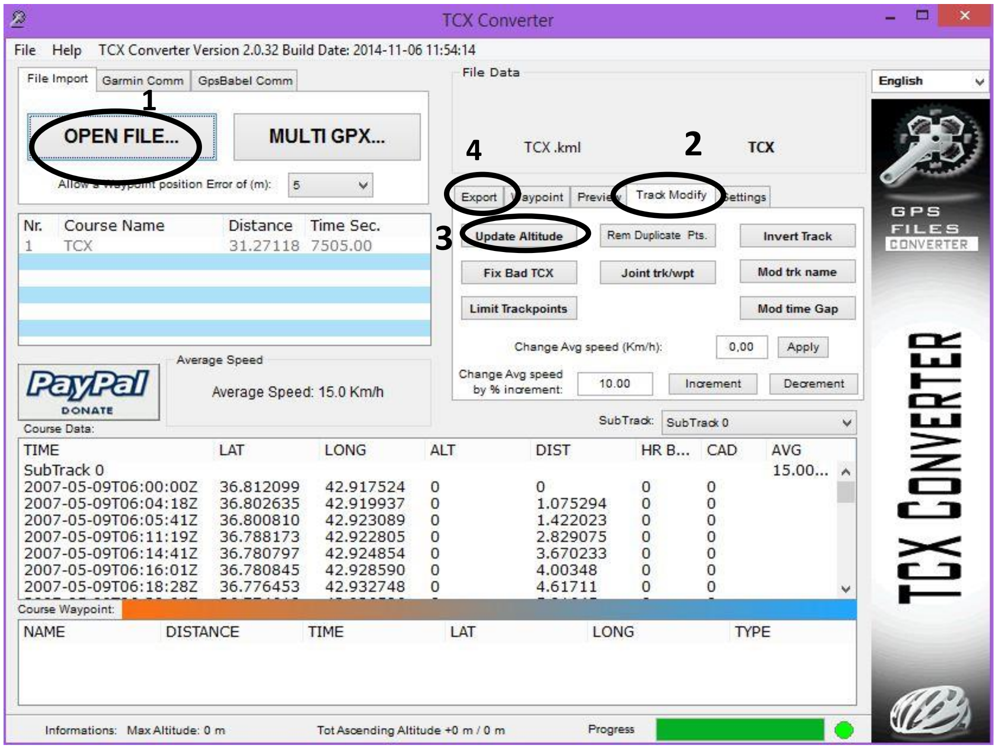
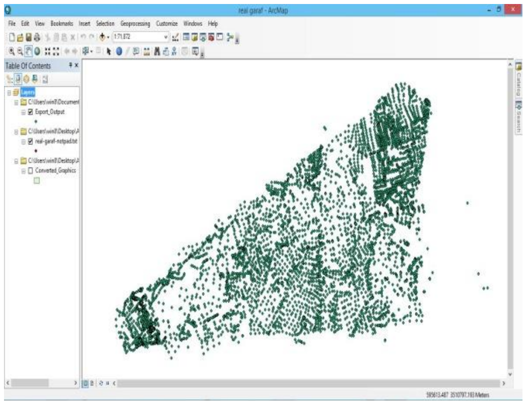


Figure 4. Extract elevation data from the KML file in TCX Converter software.

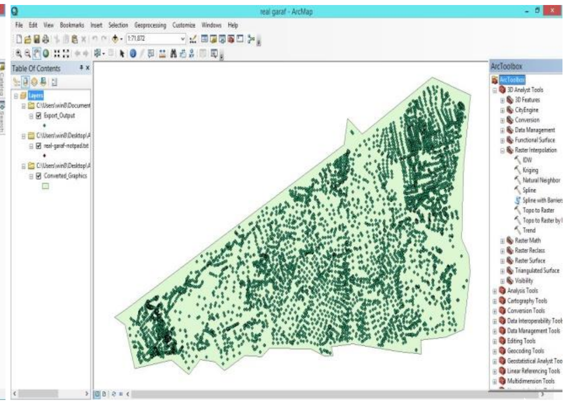
After completing the steps of coordinates processing for Al-Gharraf region for both sources reference and Google Earth Pro, DEMs were created in four methods: Kriging, spline, IDW, and natural neighbor using Arc Map software.

7. THE PRODUCTION OF DEM IN ARCMAP

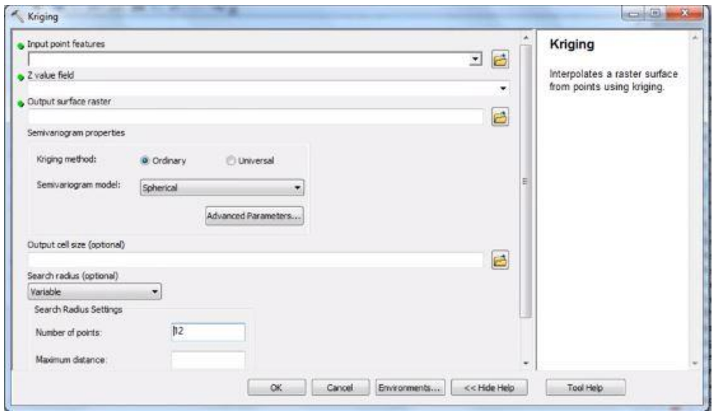
The first step for producing DEM using GIS is selecting add X Y data. A window will open, the points will appear on the screen, as shown in **Fig. 4**. A polygon is created around the points so that DEM is within the boundaries of the study area as shown in **Fig. 5**. In the toolbar, ArcToolbox is selected which completed application created through Esri. It gives a reference to the toolboxes to facilitate user interface in ArcGIS for getting and organizing a combination of geoprocessing instruments, models and scripts. The 3D Analyst Tools is selected which includes several options, click on Raster Interpolation which contains DEM methods: IDW, Kriging, natural neighbor, and spline. Clicking on one of the ways, the window will open as shown in **Fig. 5**. The DEM method is selected; a window contains several steps will appear. It includes setting points and their height, as well as the locating of output saving.



(a)



(b)



(c)

Figure 5. (a)The points are added to the GIS software, (b) A polygon is created around the points, (c) DEM production.

Fig. (6) to **(9)** present the output of DEM generation using four different methods. These DEMs were extracted from General Directorate of Surveying data which are considered as reference data source.

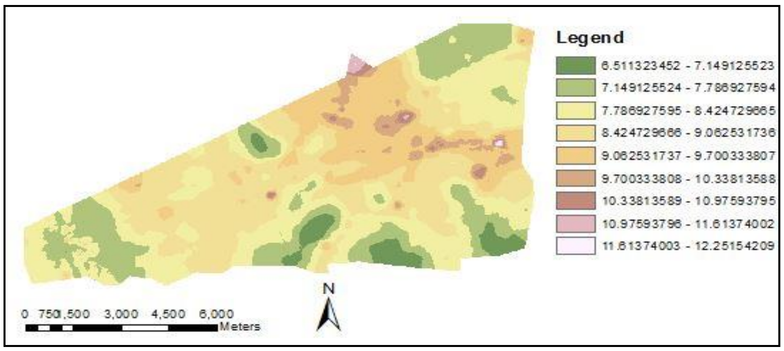


Figure 6. Digital elevation model for Al Gharraf for reference data (kriging method).

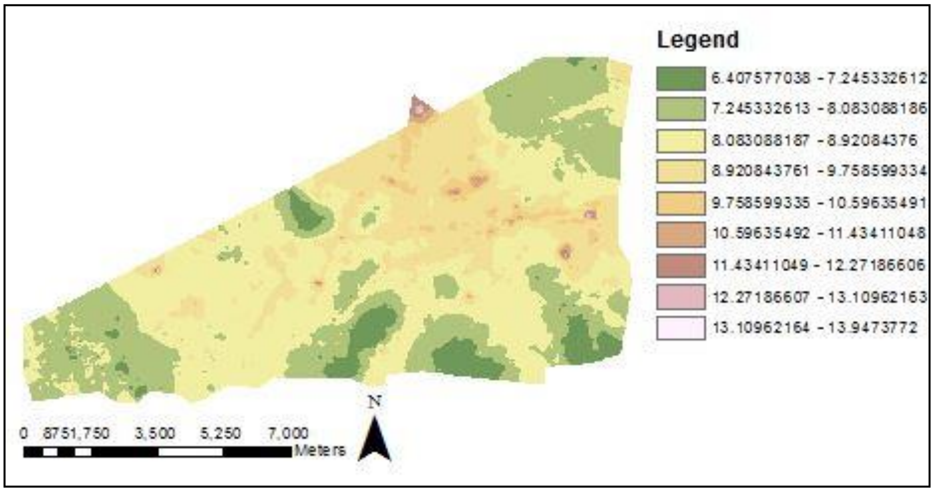


Figure 7. Digital elevation model for Al Gharraf for reference data (IDW method).

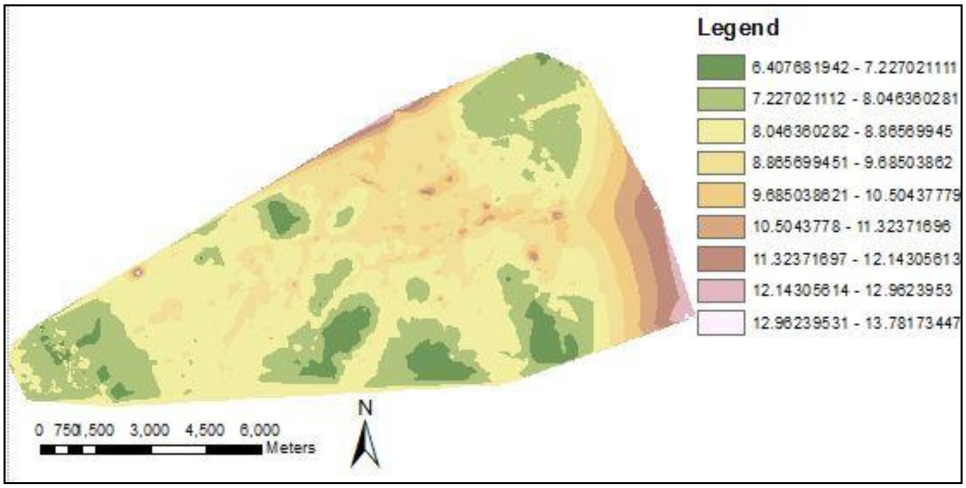


Figure 8. Digital elevation model for Al Gharaf for reference data (natural neighbor method).

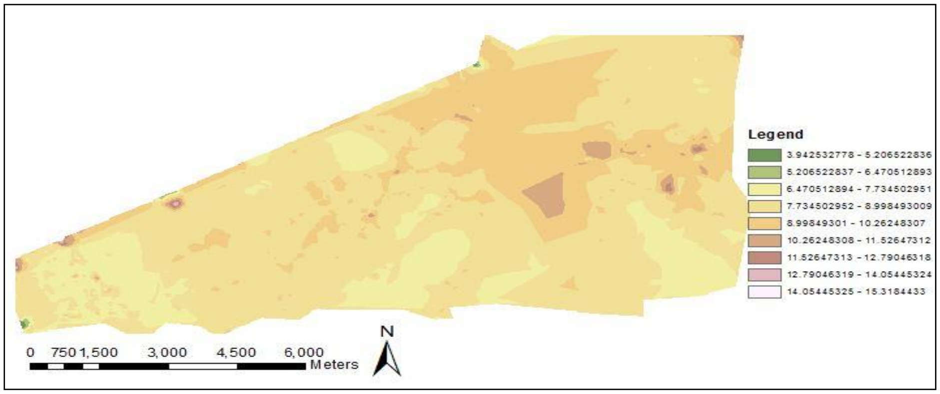


Figure 9. Digital elevation model for Al Gharaf for reference data (spline method).

Figures (10) to **(13)** present the DEMs extracted from data obtained from Google Earth Pro which are considered as open-source data. Several methods were used to create DEM from Google Earth data using GIS such as kriging, IDW, spline, and natural neighbor.

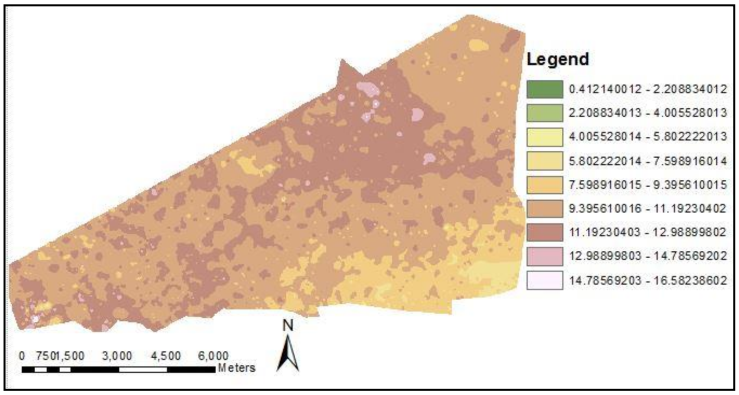


Figure 10 .Digital elevation model for Al Gharraf for Google earth data (IDW method).

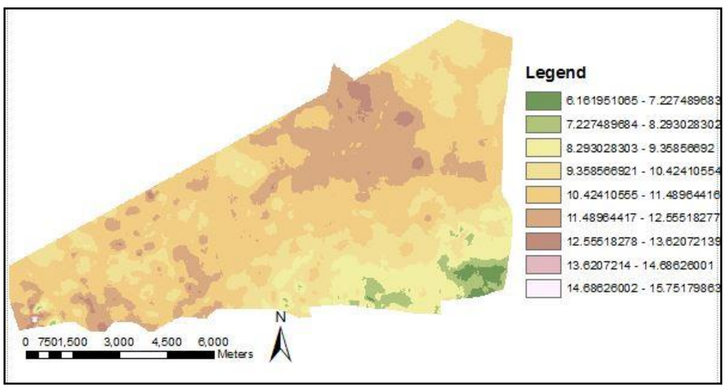


Figure 11. Digital elevation model for Al Gharraf for Google earth data (kriging method).

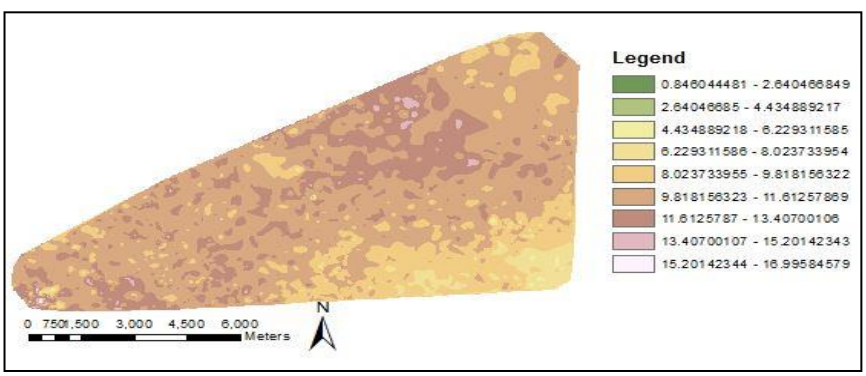


Figure 12. Digital elevation model for Al Gharraf for Google earth data (natural neighbor method).

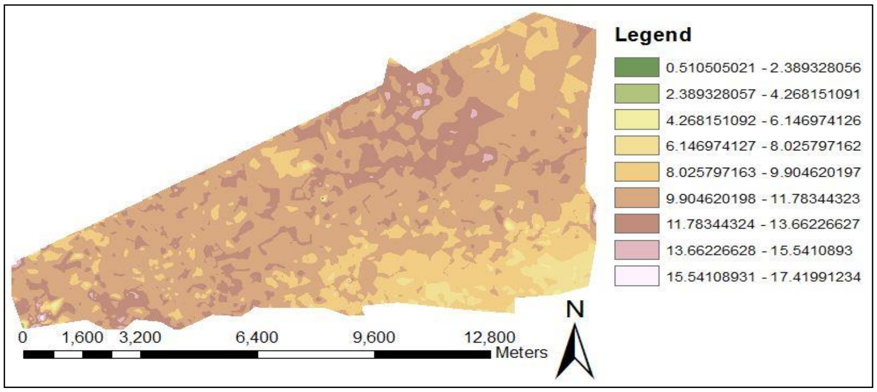


Figure 13. Digital elevation model for Al Gharraf for Google earth data (spline method).

8. COMPARING DEMS DATA USING CIVIL 3D SOFTWARE

AutoCAD Civil 3D software supports several types of surfaces such as grid surfaces, formed from points that lie on a regular grid (for example, Digital Elevation Models (DEMs). In this research, the Civil 3D was used to make the surface of squares for the DEMs data. To compare the exporters for each method AutoCAD Civil 3D software is used and then the results are exported where each cell (after interpolation) in the reference source is compared with the corresponding cell in the source of the Google Earth where the elevations values are compared. The first step is defining the projection-type where through setting press on Drawing and then choosing Edit Drawing then the Drawing settings window will open a determine the projected that is represent Iraq, as shown in **Fig. 14.**

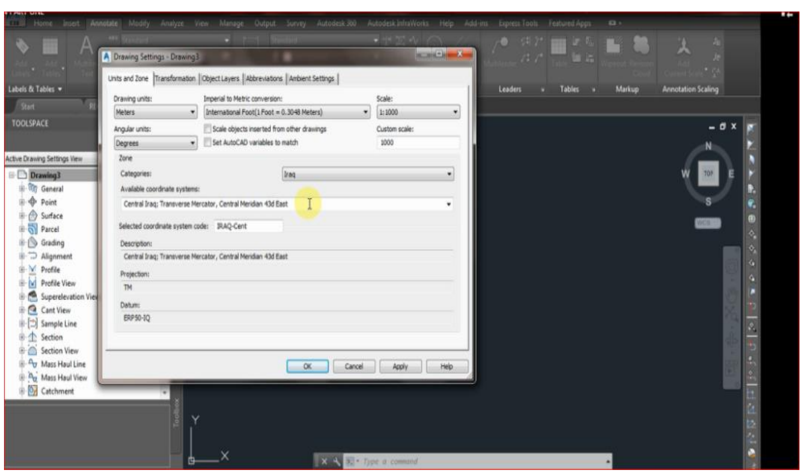


Figure 14 .The projection definition.

The second step is creating a surface depending on the DEM data, which was imported from GIS, as explained in **Fig. 15**.

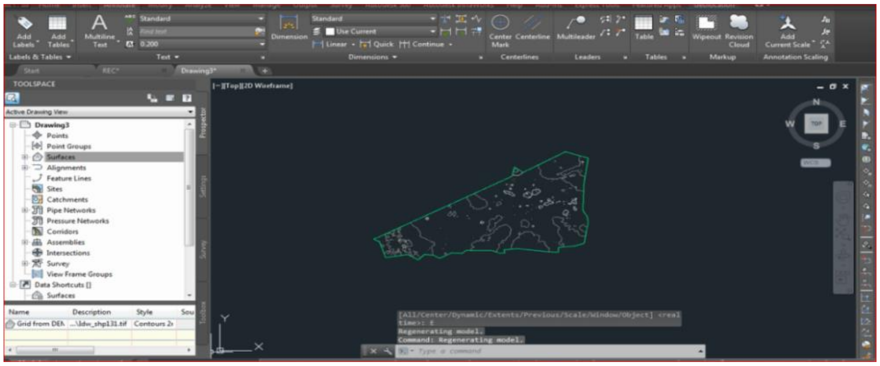


Figure 15. Create a surface.

Then removing and isolating everything that exists on the program except for point information that shows the point level using the ISOLATE directive, **Fig. 16**.

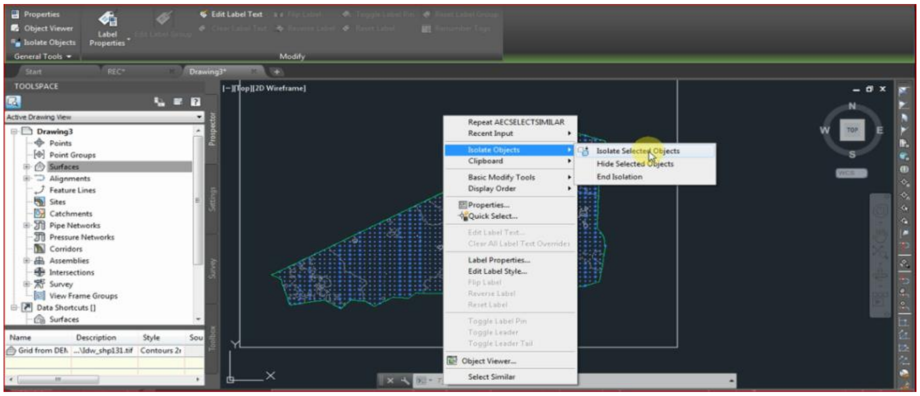


Figure 16. One of the work steps in Civil 3D.

After completing this process, the data will be exported and saved as an Excel file, **Fig. 17**.

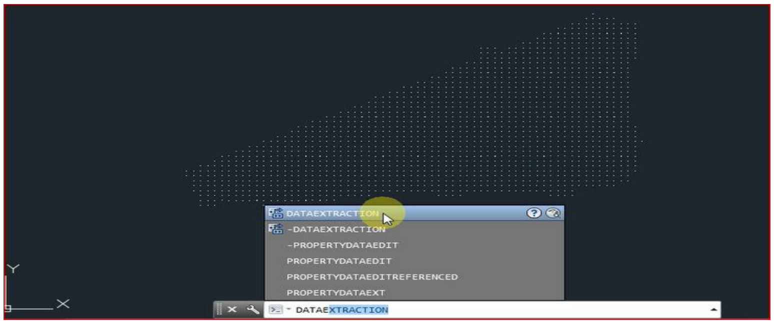


Figure 17. How to extract data.

9. RESULTS AND DISCUSSION

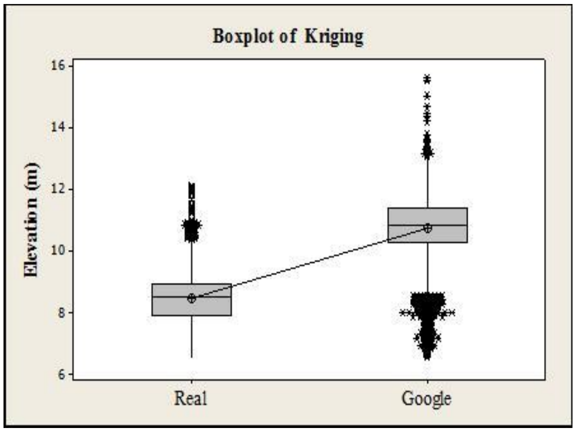
The findings showed that the t-value was 295.06, and the p-value was 0.000 which is less than the (0.05). The mean of the reference data was 8.453 m, while the mean value of the Google Earth Pro source was 10.734 m for DEMs produced using IDW method. This proves that there is a difference in the average deviation of the accuracy of the DEM data in different sources for this study area which was -2.280 m. The same procedure has been followed for comparing the elevations in Kriging, spline and natural neighbor methods for two sources. The t-value was 315.87, and p-value was 0.000 which is less than the (0.05). The mean of the reference source was 8.477 m, while the mean value of the Google Earth Pro source was 10.74 m for DEMs produced using Kriging method. This proves that there is a difference in the average deviation of the accuracy of the DEM data in different sources for this study area which was -2.261m. The t-value was 272.97, and p-value was 0.000 which is less than the (0.05). The mean of the reference source was 8.399 m, while the mean value of the Google Earth Pro source was 10.75 m for DEMs produced using spline method. This proves that there is a difference in the average deviation of the accuracy of the DEM data in different sources for this study area which was -2.351m.

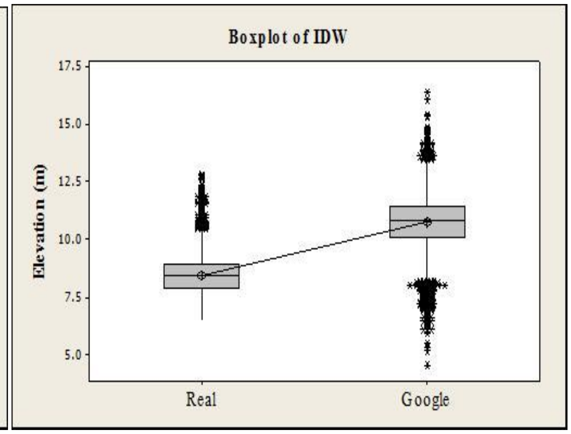
The t-value was 296.62, and p-value was 0.000 which is less than the (0.05). The mean of the reference source was 8.400 m, while the mean value of the Google Earth Pro source was 10.74 m for DEMs produced using natural neighbor method. This proves that there is a difference in the average deviation of the accuracy of the DEM data in different sources for this study area which was -2.340 m.

The statistics for assessing the accuracy of two data sets using Minitab software by applying two-sample T-test are demonstrated in **Table 2**. Box plot of two-sample tests is **shown in Fig. 18.**

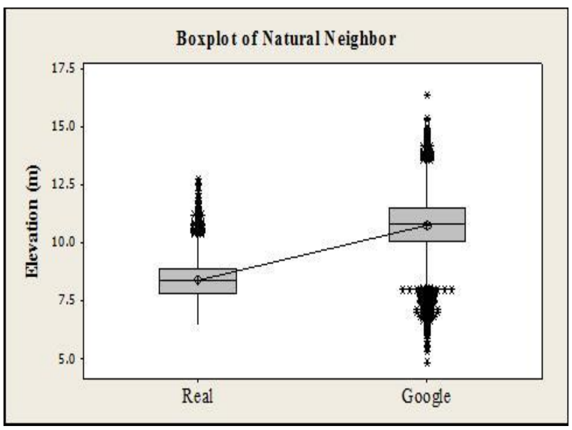
Table 2. The statistics for assessing the accuracy of two data set applying two-sample T-test.

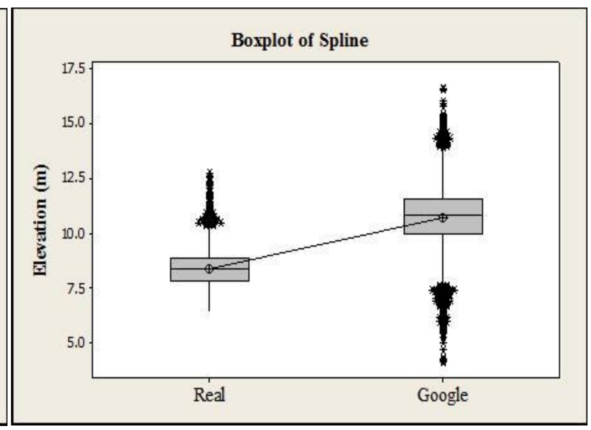
Study area	No.of points		T-value			
	Real	Google earth pro	Kriging	IDW	Spline	Natural Neighbor
Garraf	30122	30122	315.87	295.06	272.97	296.62





(a) (b)





(c) (d)

Figure 18. Box plot to analyze the differences in elevations of Al Garraf case study of two data sources for (a) kriging, (b) IDW, (c) natural neighbor, and (d) spline method.

10. HISTOGRAM ANALYSIS

The histogram analysis showed that the elevations of IDW method of ranging between (6.48 - 12.86) meters for the reference source while the elevations of Google Earth source displays that elevations ranging between (4.56-16.38) meters, **Fig. 19 (a)**. The histogram analysis showed that the elevations of Kriging method range between (6.55-12.12) meters for the reference source while the elevations of Google Earth source displays that elevations range between (6.58-15.59) meters, **Fig. 19 (b)**. The histogram analysis showed that the elevations of spline method of range between (6.45-12.74) meters for the reference source while the elevations of Google Earth source displays that the elevations range between (4.18-16.61) meters, **Fig. 19 (c)**. Also The histogram analysis showed that the elevations of natural neighbor show that the elevations range between (6.46-12.77) meters while the elevations of Google Earth source displays that the elevations range between (4.83-16.39) meters, **Fig. 19 (d)**.

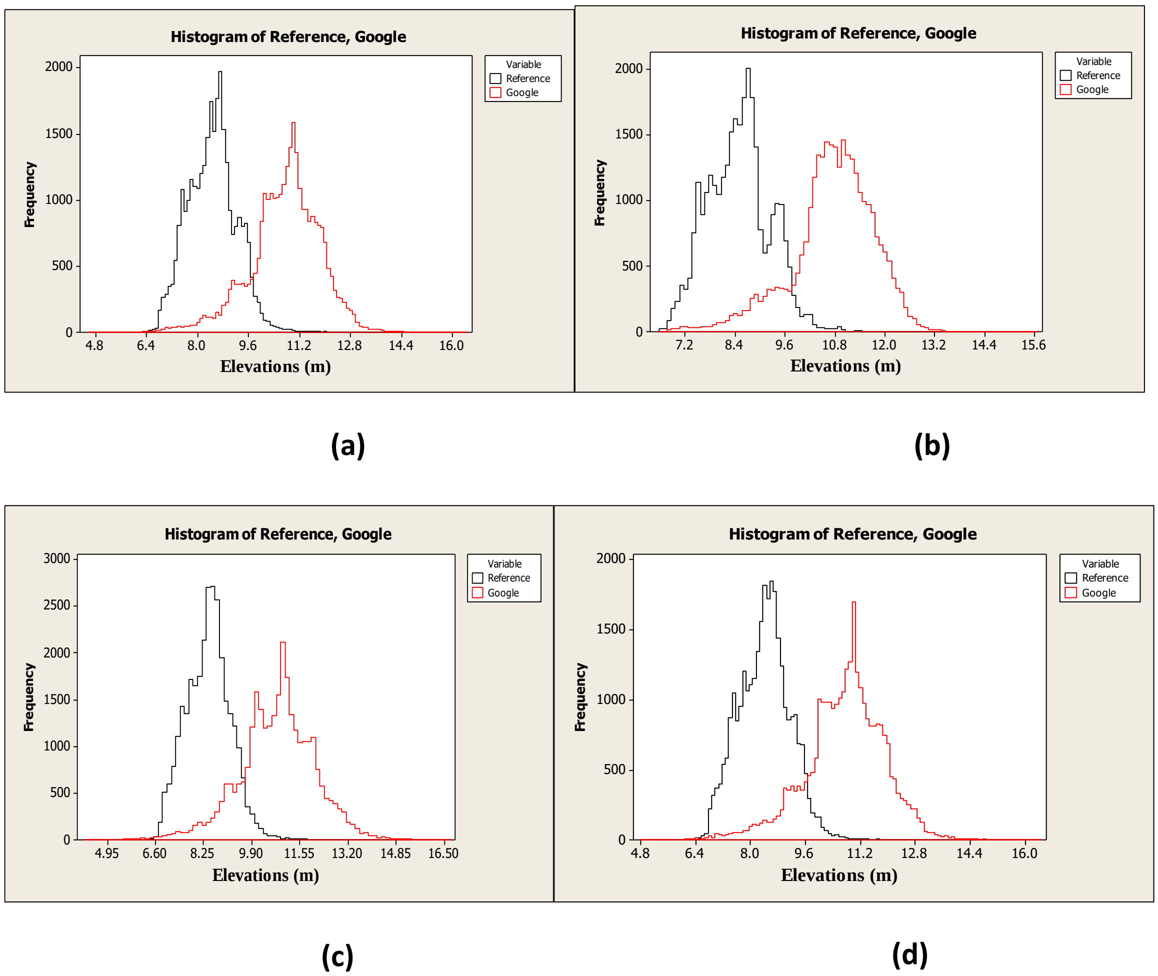


Figure 19. Histogram of (a) IDW, (b) Kriging, (c) spline, and (d) natural neighbor method of AL-Garraf.

From these figures, it can be also noted that there is a great peak on the left side for reference source and great peak on the right side for Google Earth source. This means that data is mismatch for both there both sources this results the best method is IDW.

From these histograms, one can see that there is a peak on the left side for reference source while in the Google Earth Pro there is a peak on the right side. This means that there is a large spacing between two data sources.

11. CONCLUSIONS

By following the research methodology, several research outcomes have been concluded. The main of these outcomes are illustrated as follows:

1. In Al-Gharaf study area the t-test showed that the t-value was (295.06m) for IDW method, (315.87m) for Kriging method, (272.97m) for spline method and (296.62m) for natural neighbor method. The results revealed that the spline method is the best way to produce DEMs from Google Earth data for Al-Gharaf study area.

2. From the statistical graphs, the box plots demonstrated that the difference between the mean of the elevations of the reference and Google Earth Pro data for four methods. From these graphs, it can be concluded that the spline is the best method for AL-Gharaf.

3. From histograms of two data sets for all methods, it can be noted that the data is a mismatch for both sources. This indicated that there is a significant difference between two data sources. Therefore, Google Earth data can be used for the purposes of no need for high accuracy.

4. Google Earth has been identified as one of its specifications is that it does not work without the Internet and does not give elevations directly because it needs another software to achieve this task.

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