Comparing Ground Survey Data with SRTM Satellite Data: Case Study in North of Iraq

HAVAL ABDULJABBAR SADEQ
Assistant lecturer

University of Salahaddin, Hawler, College of Engineering,
Surveying Engineering Dept, Erbil, Iraq
EMAIL: haval.js@gmail.com

ABSTRACT

In this paper a comparison between DEMs, which generated from ground survey using total station and DEM generated from SRTM DEM (Space Shuttle Radar Topography Mission) with 90m spatial resolution, has been done. The comparison achieved in two different areas, area-1 (covers 1,384,707.00 square meters) and area-2 (covers 549,041.00 square meters). The topography of the area-1 was non flat, while the area-2 was approximately flat. The comparison achieved using two different methods, first method was an evaluation for contour lines which carried out between ground survey and SRTM DEM contour maps, second method was a spatial analyst test using statistical functions (e.g. mean, standard deviation STD). The comparison showed that the variation of SRTM data and ground survey data is small in flat areas and increases in high grade areas. The software which is been used in comparison was ArcGIS package.

KEY WORDL: DEM, SRTM, ArcGIS, Geospatial

مقارنة بيانات المسح الارضي مع بيانات الاقمار الصناعية الـ SRTM :موقع الدراسة شمال العراق

هه فال عبد الجبار صادق
مدرس مساعد
جامعة صلاح الدين – كلية الهندسة – قسم المساحة

الخلاصة

في هذا البحث تم اجرا مقارنة بين الـ DEMالمعتمد على جهاز توتل ستيشن و الـ DEM المعتمد على SRTM (مكوك الفضاء الراداري للمهمة الطبوغرافية) وبدقة 90م . المقارنة تم في منطقتين مختلفتين ، منطقة ـ1 (تغطي مساحة 1,384,707.00 م2) ومنطقة - 2 (تغطي مساحة 549,041.00 م2) . الطبوغرافيا للمنطقة ـ1 كان غير منبسط ، بينما الطبوغرافيا للمنطقة ـ2 كان منبسط. تم اجرأ المقارنة باستعمل طريقتين مختلفتين , اولاً مقارنة الخطوط الكنتوريةالناتجة من المسح التقليدي ومن الـ SRTM لكلتا المنطقتين , ثانياً استخدم التحليل الاحصائي (الانحراف المعياري والوسيط). اظهرت المقارنة ان التباين ظئيل بين بيانات الـ SRTM والمسح التقليدي في المناطق المنبسطة وتزداد في المنطق ذات الانحدارات العالية . تم استعمال برنامج ArcGIS لاجراء التحليلات

1. Introduction

The analysis of automatically extracted terrain features based on Digital Elevation Models (DEM) such as slope gradient, slope aspect, curvature, flow paths and delineate drainage networks, is always a kind of fundamental work for many geoscientists. Shuttle Radar Topography Mission (SRTM) offers the opportunity to extend terrain analysis from local to global. However, it is a main deterrent for geoscientist to deal with massive DEM data even in a limited interesting research area [1]. DEM can be considered as a basic requirement in the variety of geospatial applications such as; extracting terrain parameters, modeling water flow or mass movement creation of relief maps, rendering of 3D visualizations, creation of physical models (including raised-relief maps), rectification of aerial photography or satellite imagery, terrain analyses in geomorphology and physical geography, Geographic Information Systems (GIS), engineering and infrastructure design, line-of-sight analysis, base mapping, flight simulation, and surface analysis. DEM (or widely known as a Digital Terrain Model) is such a model commonly obtained from raster images with the remote sensing method [2]. The data which is been used in this research was SRTM C-band DSMs provided by Global Land Cover Facility (GLCF) from Earth Science Information Partnership at the University of Maryland [3]. The accessibility for SRTM DSM used in the study was only with spacing of 3", which corresponding to approximately 90m with some gaps exist in very steep areas. This paper evaluates the accuracy of SRTM DEM (Shuttle Radar Topography Mission) with surveyed area using survey instrument such as total station. Furthermore, evaluation of DEM accuracy is done by contour lines comparison and statistically analyzing the height different in the selected area, moreover the analysis achieved by using ArcGIS software package [4].

2. Source of Data Used in Comparison
2.1. SRTM Data

On February 11, 2000, the (SRTM) Shuttle Radar Topography Mission payload onboard Space Shuttle Endeavour launched into space, spearheaded by the U.S. National Geospatial-Intelligence Agency (NGA) and the U. S. National Aeronautics and Space Administration (NASA) produced the most complete high-resolution digital topographic database of the Earth [1]. SRTM took place to get the world's most comprehensive set of elevation data. Though the data with the best resolution is subject to military use, the resolution of the data that is available can be useful for public use also. SRTM is mounted on a Space Shuttle and obtains Earth surface data by remote sensing technology utilizing synthetic aperture radar. Obtained data will be converted into height data called a Digital Elevation Model (DEM), and will be utilized to generate a more precise three-dimensional map of larger observation area of the Earth than has ever been possible. The SRTM mission has been the first mission using space-borne interferometric SAR. The advantage of using radar is the independence of cloud cover and daylight. Therefore within the mission was possible to produce a homogeneous and dense DTM of the Earth. To assess the quality of IFSAR DTMs it is necessary to understand the principles of SRTM technique. The method is based on a spatial similarity transformation without using any kind of control point information [2]. The high-resolution, digital, three-dimensional topographic map produced from this data will be disclosed to the general public in the hope that it will be used in various fields. The SRTM data set in form of the tiles of $1°×1°$ with $3×3$ arc second resolution for all topographic area between the latitudes of 60° in north and south hemisphere is freely available from the Internet (NASA, 2005) . The original data files at intervals of 1 x 1 arc

second resolution (about 30 meters at the Equator) exist for the United States only (see Table 1). Although some areas of missing data (voids) are still present.

Table(1) Specifications for SRTM "finished" 1 and 3 arc second data

Product	Resolution	Projection	Horizontal Datum	Vertical Datum	Vertical Units	Cell Size (deg)
Shuttle Radar Topography Mission (SRTM) 1 Arc Second (~30m resolution)	1 arc second (approx. 30m) conterminous US	Geographic	WGS84	WGS84/EGM96 geoid	Meters	0.00028
Shuttle Radar Topography Mission (SRTM) 3 Arc Second (~90m resolution)	3 arc second (approx. 90m)	Geographic	WGS84	WGS84/EGM96 geoid	Meters	0.00083

2.2. Study Area and Data Collection

Experimental datasets DEM used in the paper is SRTM3 with accuracy 90m which is been downloaded from ftp server ftp://ftp.glcf.umiacs.umd.edu/glcf/SRTM/stow/stow/ [3] this data is currently distributed free of charge by USGS also is available for download from the National Map Seamless Data Distribution System, or the USGS ftp site and the data was arranged in grid (see figure 1). The SRTM data is available as 3 arc second (approx. 90m resolution) DEMs [5]. The file format was in tif, and cell size is 0.000833333 decimal degrees, the test site has been selected in two different areas in the north of Iraq, the areas was marked as area-1 and area-2 (see figure 2), the topography of both areas have been illustrated in the DTMs (see figure 3). The area-1 is located in north of Erbil governorate, the lower left corner coordinate was(428109, 4038091) and upper right corner coordinate was(431045, 4038915), this area was characterized by non flat terrain and the number of points were taken for this study were 4676 points covering 1,384,707.00 square meters, and the range of elevations was from 420.5m to 472.2m (see figure 4), while the area-2 is in north-west of Dohuk Governorate, the lower left corner coordinates according to UTM was(269061, 4106861) and upper right corner coordinates was (269768, 4108042), the area was characterized by flat terrain, the number of points were taken for this study were 1631 points covering 549,041.00 square meters and the range of elevations was from 582m to 696m (see figure 5). These data gathered using total station and it was distributed irregularly (see figure 6).

Figure-1: SRTM data sheets distributed in north of Iraq
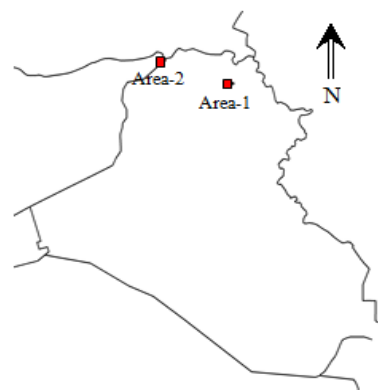
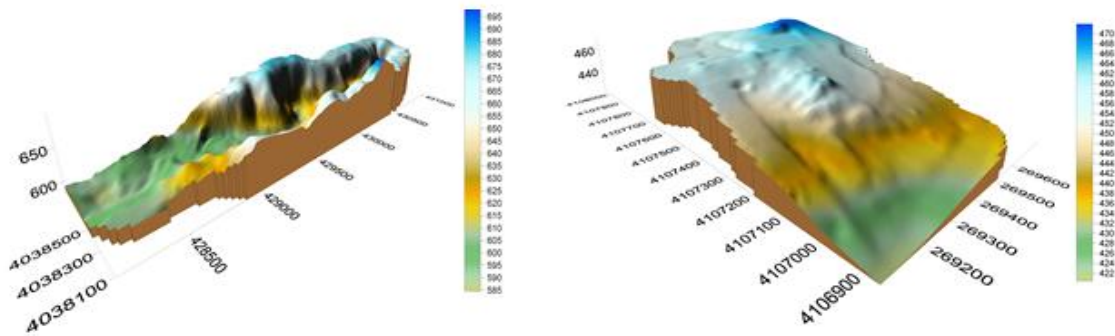**Figure-2: Iraq Map illustrate the study areas**

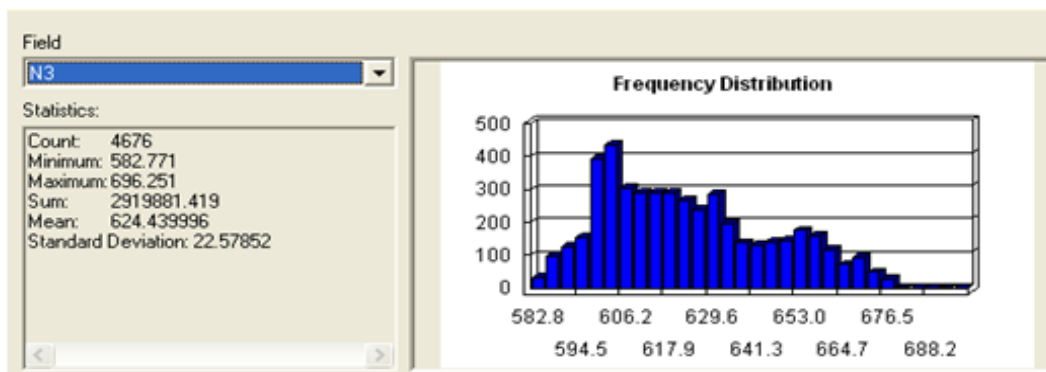Figure-3: 3D model for study area (a) area-1 (b) area-2

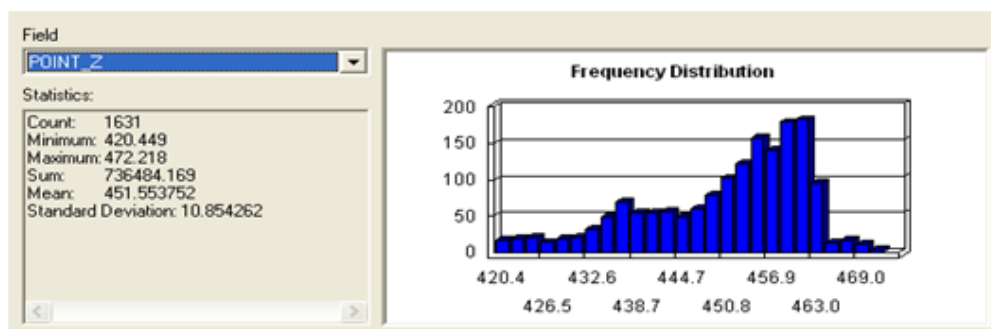Figure-4: Area-1 elevation histogram and statistical analysis

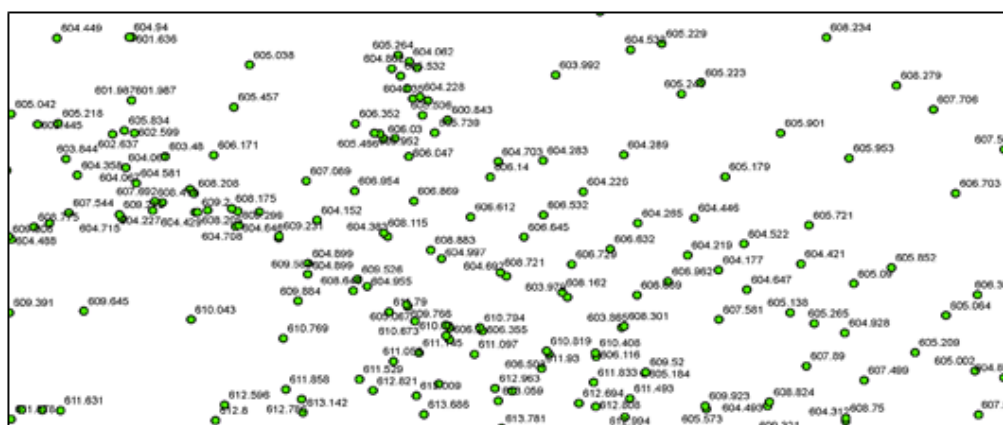Figure-5: Area-2 elevation histogram and statistical analysis

Figure-6: Some part in area-2 shows irregularly distributed points

3. The Methodology Used In Data Analysis

3.1. Data Processing

To show the general working steps in this research, two files have been downloaded from the SRTM ftp from the mentioned site[3], both files was in (tif) format, the first one named N36E44 which covers the area-1, and the other named N37E42 which covers the area-2. Each file covers an area 110km by 88km, so it was necessary to extract a specified area in order to reduce the analysis period and make it faster, a TIN has been produced from the extracted parts (see figure 7) and then a contour map has been produced. Since the cell sizes of the SRTM was about 90m, it was necessary to reproduce a new raster from TIN but with cell size 11m (see figure 8) this small cell size gives more realistic idea about the assessment of the variation during the comparison process. The next stage is survey point processing, in this stage the points has been converted into shape file using ArcCatalogue software which accompanied with ArcGIS software, because the coordinated of SRTM are in Geodetic system and coordinates of survey points are in UTM system based on GARMIN GPS, it was necessary to unify both coordinates, and transform the point coordinates from Universal Transverse Mercator (UTM) Zone 38N to Geodetic coordinates, using transformation and projection tool. The next step was producing a TIN and then contour map for the areas (see figure 9) and after that producing a new RASTER grid, in order to manage comparison process with SRTM DEM-raster.
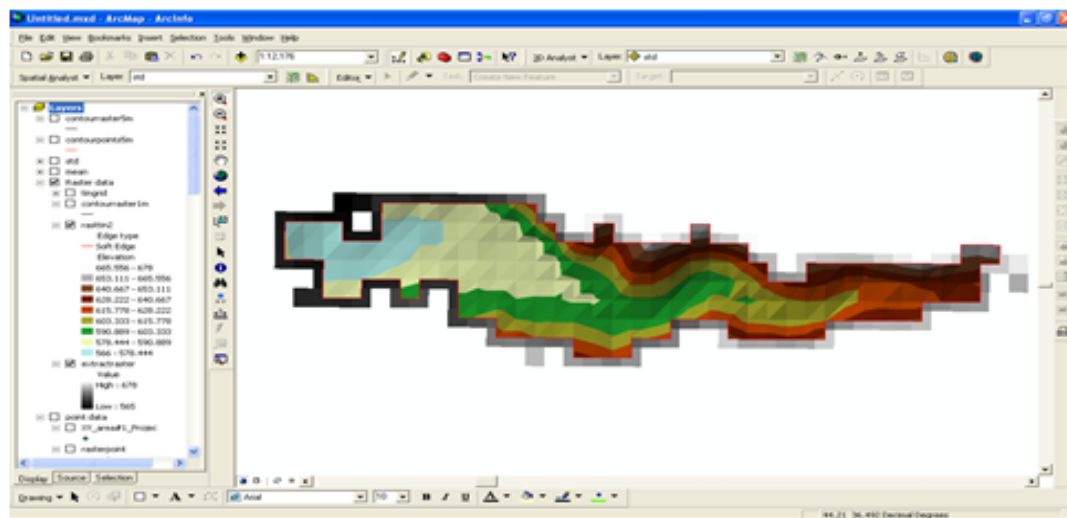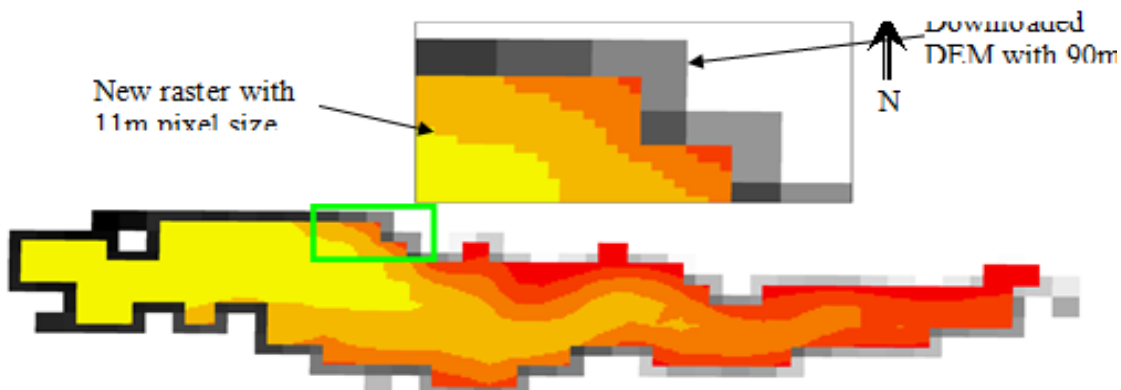

Figure-7: Creating TIN from extracted DEM in area-1

Figure-8: Raster with big resolution (top) and small resolution in back explain the cell size in area-1
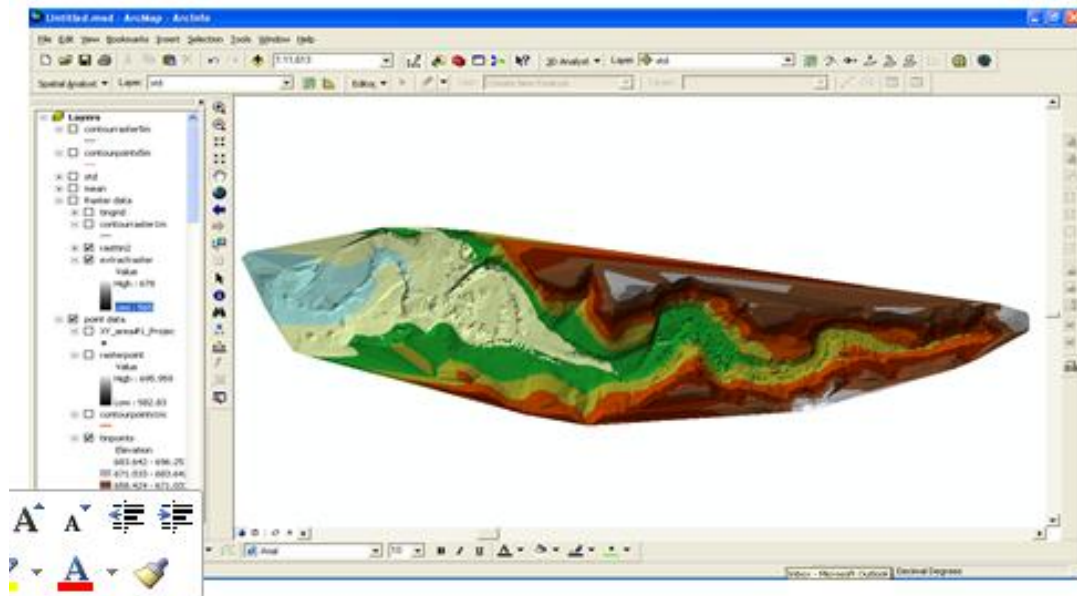
Figure-9: TIN created from survey points in area-1

3.2. Contour matching and variation

To achieve the comparison between the contours map which is been created from DEM (black color) and the contour map which is been created from survey points (red color) (see figure 10). First, a contour map with interval 5m for both SRTM and Total Station surveyed data has been produced in area-1, due to the high inclination topography, from that it can be observed the line trace was similar to some extent in both contour maps but there was a shifting between the lines, for the test the contour line with elevation-625m has been examined, which is been colored with cyan color, it was visible that the lines was convergencing to some extent until they intersect then the divergence starts until it reaches to 390m.

Regarding the test area-2 the contour lines interval was 1m because the topography of the area was flat, the contour line with elevation 58 has been selected for comparison, it is been noticed that, the contour lines first intersect and then they start to diverge until they reach to 90m distance between them.
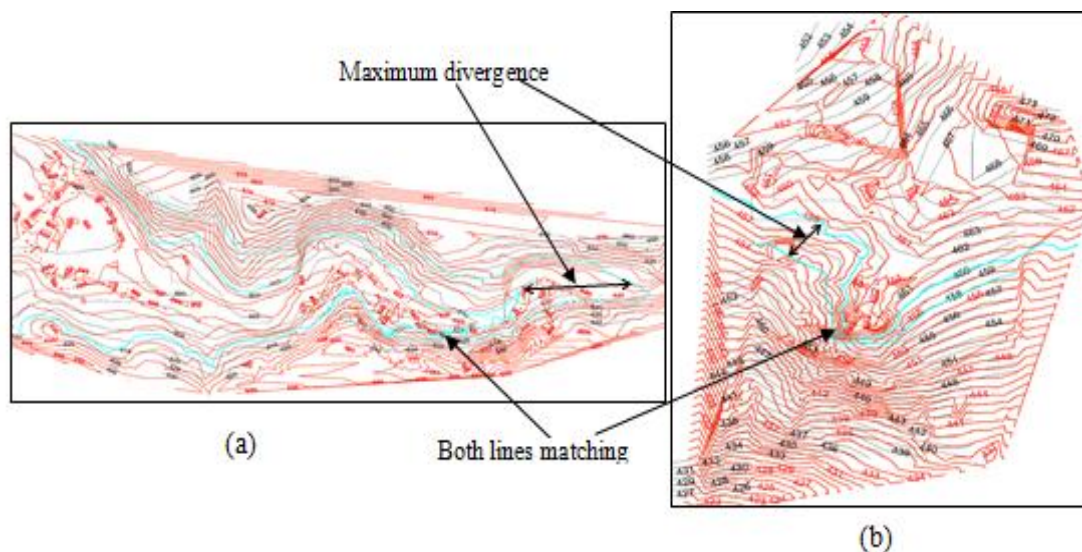

Figure-10: Overlaying contour maps to examine the variation (a) area-1, (b)area-2

3.3. Spatial analyst

Visual inspections using contour lines have bean used to inspect the variation, but that method does not gives widespread indication for the comparison. Accordingly it was necessary to use another mechanism for the comparison to get an overall impression about the variations between two sets of data, this new mechanism is done using ArcGIS spatial analyst, a common way to approach that result is by performing a statistical analysis to show the range of variation in the data, it is also used to examine the data distribution, where within the ArcGIS software the development of the histogram for the distribution is associated with following statistical parameters, mean and standard deviation. Conclusions were drawn using visualization and exploratory statistical techniques. Statistical analysis functions in ArcGIS Desktop are either nonspatial (tabular) or spatial (containing location), nonspatial statistics are used to analyze attribute values associated with features. The values are accessed directly from a layer's feature attribute table. Examples of nonspatial statistics include the mean and standard deviation.

3.3.1. Mean

The mean (or more correctly, the arithmetic mean) is the average value of the observations, it is calculated as the sum of the observations, divided by the number of observations Equation A.1.

$$mean \quad \bar{x} = \frac{\sum x}{n} \quad \text{-----------------} \qquad \textbf{Eq.(A.1)}$$

Zonal statistics are used to calculate the mean elevations, between SRTM and Survey point, for the area-1 and area-2 (see figure 11&12). Alternatively, the user might want to know type of elevation distribution in each elevation zone (variety), this will be by producing histogram for both regions -1&-2 (see figure 13&14) which gives index about the elevation distribution, in region -1 the elevation range 576-586 lay in the middle and the other high elevations distributed at the edges, but in region-2 the low elevation 423-429m distributed in the south while the higher elevation distributed in the north east , the number of the pixel can be counted from histograms for both regions
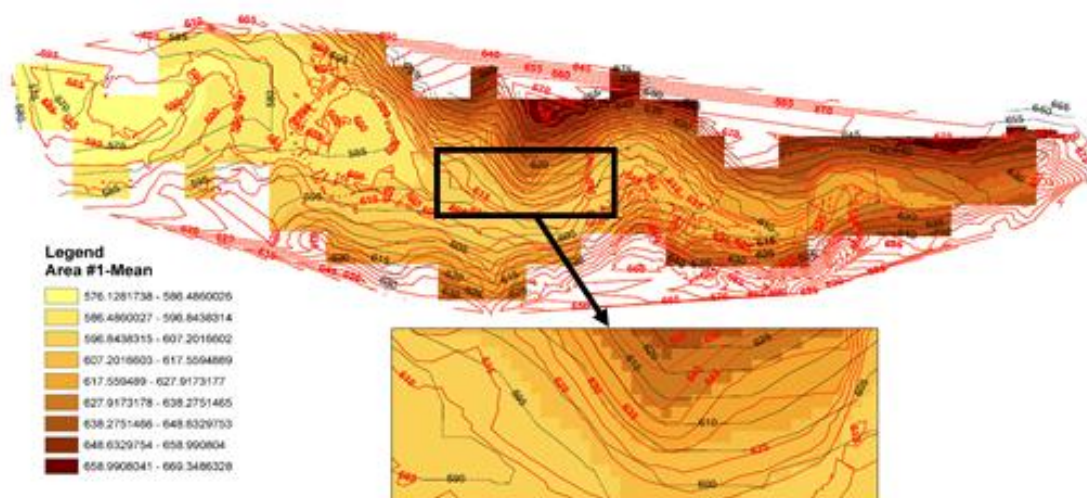

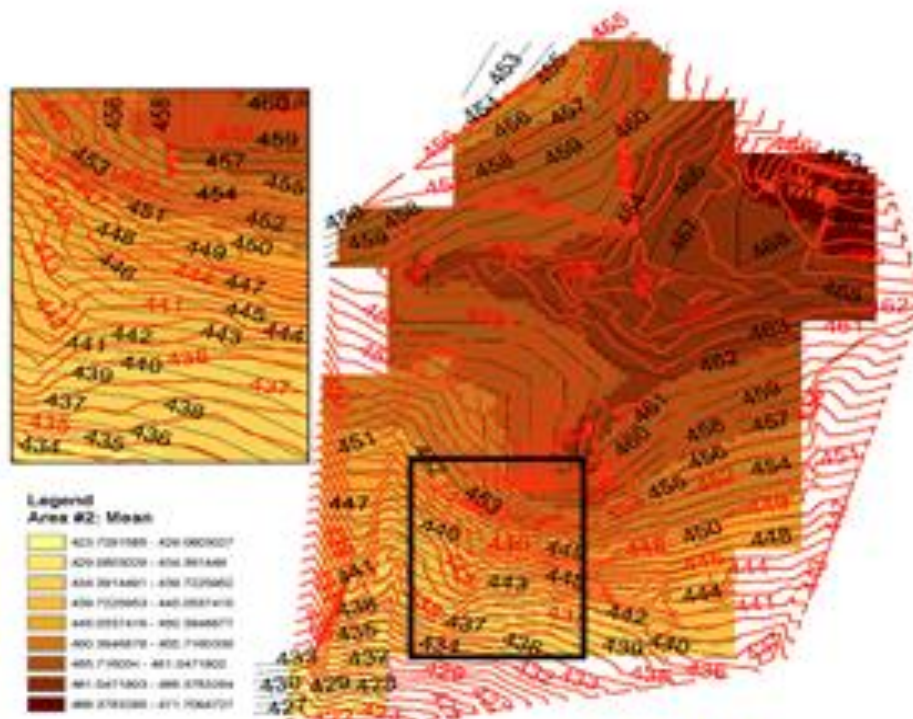**Figure-11: mean elevations in study area-1**

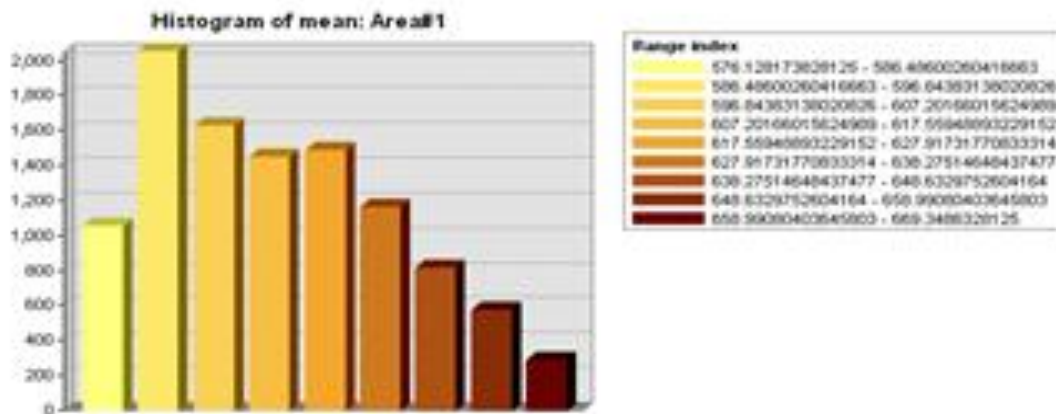Figure-12: Mean elevations in study area-2

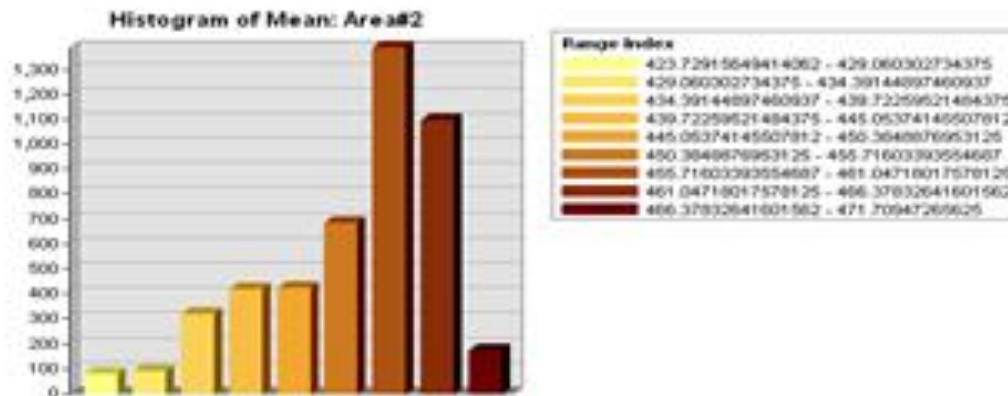Figure-13: Histogram of mean elevation for area-1

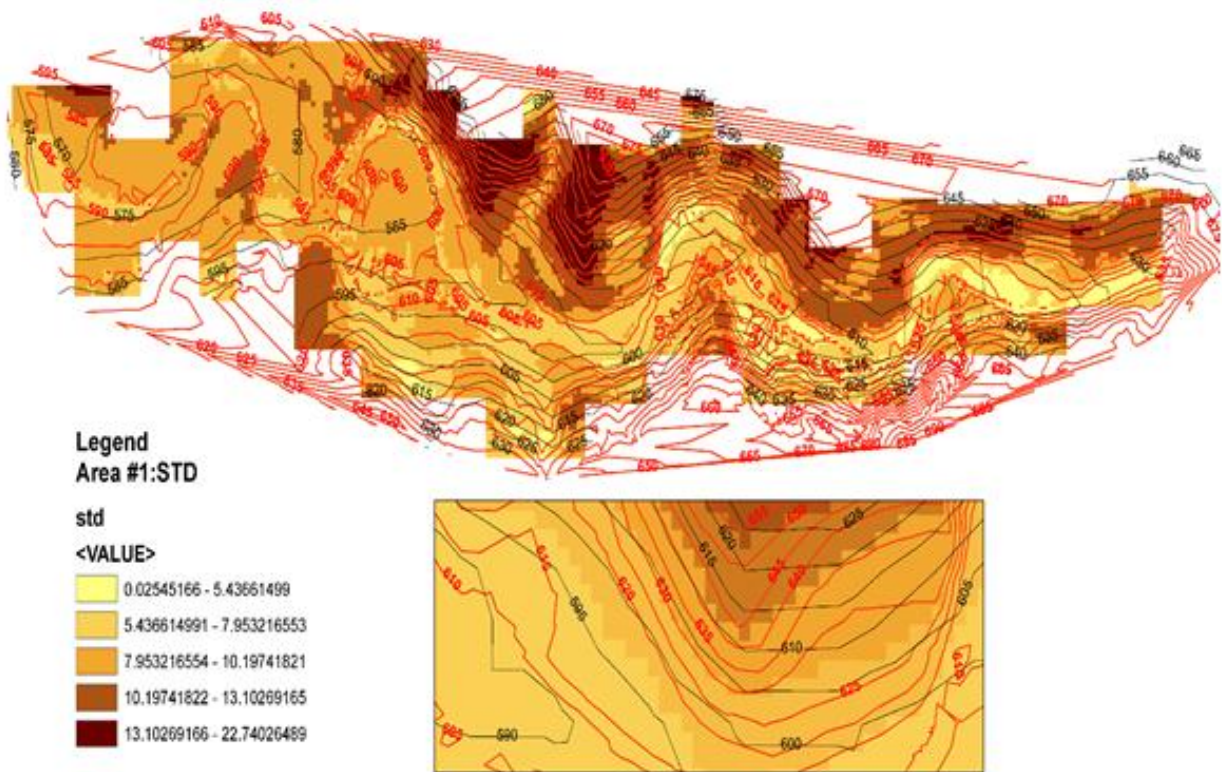Figure-14: Histogram of mean value for area-2

3.3.2. Standard Deviation

The standard deviation is the most common measure of statistical dispersion, measuring how widely spread the values in a data set are, and tells you how tightly all the various examples are clustered around the mean (middle or average) in a set of data, and to see how closely each individual observation clusters about it. It sums the square of each difference ('sum of squares') and divides by the number of observations, Equation A.2.

$$Std = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (xi - \bar{x})} \quad \text{-----------------}$$ **Eq.(A.2)**

Zonal statistics are used to calculate the elevations standard deviation STD, between SRTM and Survey point, for the region-1 and -2 (see figure 15&16). Alternatively, the user might want to know type of elevation score distribution in each elevation zone (variety), this will be by generating histogram for both regions -1&-2 (see figure 17&18) which gives index about the elevation distribution.

Legend
Area #1:STD

std
<VALUE>

	0.02545166 - 5.43661499
	5.436614991 - 7.953216553
	7.953216554 - 10.19741821
	10.19741822 - 13.10269165
	13.10269166 - 22.74026489

Figure-15: Standard deviation of elevations in study area-1

As was apparent in the previous histograms in (see figures 17&18), the elevation variant distribution is jagged because the median is discrete. As it can be noticed that the standard deviation spreaded from 0.025 to 22.74 for region -1 , of these values can be and from 0 to 3.68 in region -2, the value of the STD can be scored from the above histograms.
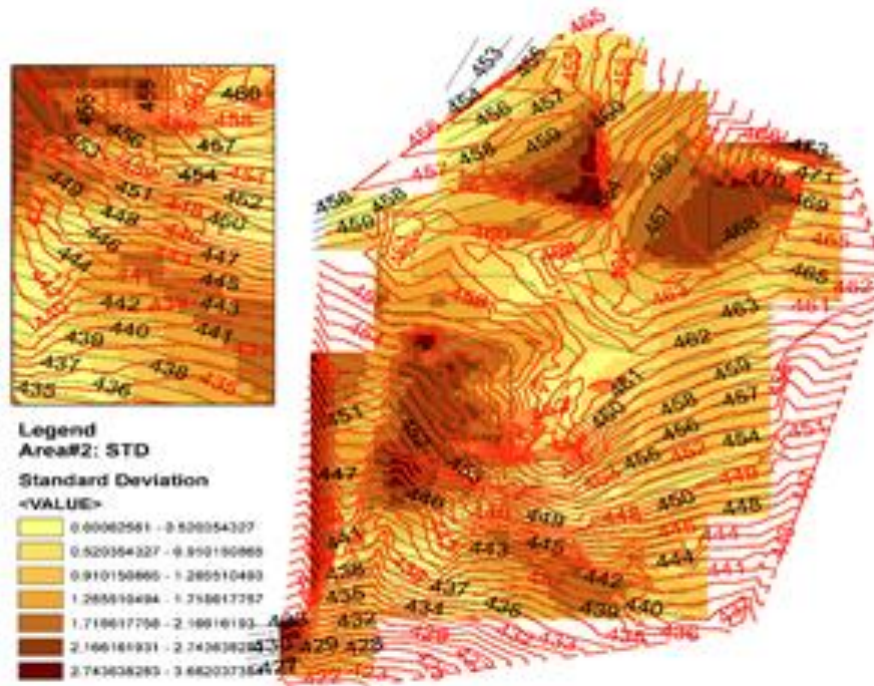
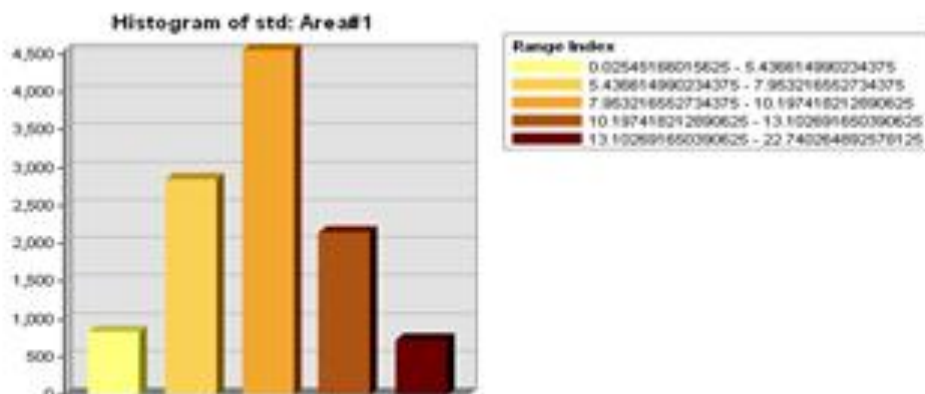**Figure-16: Standard deviation of elevations in study area-2**

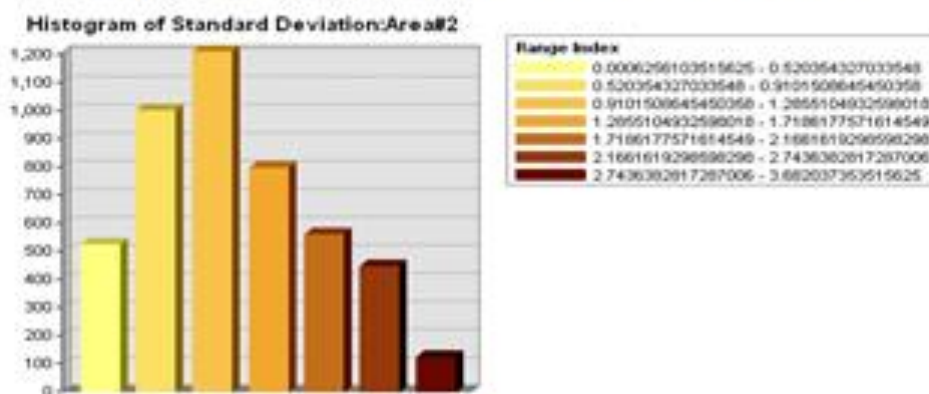**Figure-17: Histogram of standard deviation value for area-1**

Figure-18: Histogram of standard deviation value for area-2

4. Conclusions

This paper assessing the quality of the SRTM data which captured by a space shuttle mission in 2000, with data gathered by using total station instrument, for the areas which have been selected in this study. The tests achieved using two different methods. First method was visual inspection achieved by matching contour maps which generated from both data. The comparison showed that the variation are varied along the contour lines between divergence and convergence, the maximum divergence in area-1 was about 390m while in area-2 was much less it was 90m. The second method was done by using statistical analysis, such as mean and standard deviation functions, with these functions it was possible to notice and measure the variation through out the whole area, in this method different results have been obtained from the comparison of both data. It can be noticed that the result for standard deviation was between 0.025-22.74 for area-1 and 0-3.68 for area-2, which means that the high standard deviation accompanied with area of high slope, and this variant in the result is due to the coarseness of the data (90m spacing) and the fact that missing portions of data were interpolated. It can be concluded that SRTM data can be used in flat areas, or areas with insignificant grade, or it should be limited to some applications such us GIS-projects, hydrological, mapping, even it can be used in preliminary design stage for projects.

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The work was carried out at the college of Engineering. University of Salahaddin