CHAPTER ONE
INTRODUCTION

1.1 Background

Nowadays, world advanced technology where most remote sensing data are recorded in digital forms makes survey works easier than a few years ago. Digital Elevation Models (DEMs) are the most widely used data structure to store and analyze topographic information in a Geographic Information System (GIS) environment. DEM is an array representation of squared cells (pixels) with an elevation value associated to each pixel. DEMs can be interpolated from irregularly spaced three-dimensional points collected from field surveys, contour lines digitized from topographic maps, photogrammetric techniques, radar interferometry, and laser altimetry. Interpolation techniques generate DEMs from the spot heights and there are several methods; namely Kriging, Inverse Distance Weighted (IDW), Topo to raster, Natural Neighbor (NN) and Spline, to say the least.

DEMs represent elevation data and are the principal digital data source for slope and aspect map coverage used in Geographic Information Systems analysis for resource management. Elevation data can be represented digitally in many ways including a gridded model (where elevation is estimated for each cell in a regular grid), a Triangular Irregular Network (TIN), and contours. There are two main approaches for generating DEM: Interpolating the regular grid from an irregularly distributed elevation data set, or generating the grid directly using photogrammetric techniques.

Topographic maps are a widely available data source in which elevation is represented by contour lines and spot heights. Ground survey techniques using total stations (electronic tachometers) or Global Positioning System (GPS) receivers are used to collect elevation data. Measurements may be made either at a randomly distributed set of point locations or in a more structured pattern such as at equal intervals along transects. The irregularly distributed contour lines, spot heights or profiles can be interpolated to create the DEM's regular matrix of elevation values. Burrough and McDonnell (1998) define interpolation as the procedure of predicting the value of attributes at unsampled sites from measurements made at point locations within the same area or region. In terms of generating DEM, the measurements made at point locations are spot heights, points along transect or the vertices of contour lines. There are many interpolation algorithms for generating surface models from point data, such as inverse distance weighting, spline fitting and Kriging (Burrough and McDonnell, 1998) and others that interpolate from contour lines (Carrara et al., 1997).

Photogrammetry provides the most frequently used data sources and techniques for generating DEM (Stocks and Heywood, 1994), either by direct generation of DEM or indirectly via its use in topographic mapping for production of contour lines. Photogrammetry either involves stereoscopic techniques for interpretation of aerial photography or digital image correlation applied to aerial photographs.

1.2 Uses of Digital Elevation Models (DEMs)

Determining attributes of terrain such as elevation at any point, slope and aspect, finding features on the terrain such as drainage basins and watersheds, new line drainage networks and channels, peaks and pits and other landforms new line of hydrologic functions, energy flux and forest fires.

1.3 Digital Elevation Models (DEMs) in ArcGIS

Digital Elevation Models are geospatial dataset that contain elevation values sampled according to a regularly spaced rectangular grid. They can be used in terrain analysis, 3D visualization, hydrological modeling, and among other applications. DEMs can be stored in several different formats however conversion into a raster dataset is often required from many processes.

1.4 Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER)

The Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) is an imaging instrument onboard Terra, the flagship satellite of NASA's Earth Observing System (EOS) launched in December1999. ASTER is a cooperative effort between NASA, and Japan's Ministry of Economy, Trade and Industry (METI), and Japan Space Systems (J-space systems). ASTER data is used to create detailed maps of land surface temperature, reflectance, and elevation. The coordinate system of EOS satellite, including Terra, is a major component of NASA's Science Mission Directorate and the Earth Science Division. The goal of NASA Earth Science is to develop a scientific understanding of the Earth as an integrated system, weather, and natural hazards land surface climatology investigation of land-surface interaction and energy and moisture fluxes, vegetation and ecosystem dynamics investigations of vegetation and soil distribution and their changes to estimate biological productivity, understand land-atmosphere interactions and detect ecosystem change volcano monitoring of eruptions and precursor events, such as gas emissions, eruption plumes, development of lava lakes, eruptive history, and eruptive potential hazard monitoring-observation of the extent and effects of wildfires, flooding, coastal erosion, earthquake damage, and tsunami damage hydrology-understanding global energy and hydrologic processes and their relationship to global change; included is evaporate transpiration from plants Geology and soils-the detailed composition and geomorphologic mapping of surface soils and bedrocks to study land surface processes and earth's history land surface and land cover change-monitoring desertification, deforestation, and urbanization; providing data for conservation managers to monitor wilderness areas,national parks, and protected areas.

1.5 Objectives

The objectives of this research are to:

1. Compare elevations determined from interpolation (Kriging) and their corresponding DEM value.
2. Determine the effect of the number and distribution of control points on accuracy of the interpolated points.
3. Determine the optimum point's distributions that give the best accuracy of Digital Elevation Models (DEMs).

1.6 Thesis Layout

This dissertation consists of five Chapters, including this introductory chapter. Chapter two reviews some of the interpolation methods. Chapter three includes study area and the methodology used the tests carried out and results obtained from these were discussed in Chapter four.

The last Chapter includes the conclusion and recommendations and suggestions for further studies.

CHAPTER TWO

INTERPOLATION

2.1 Introduction

Interpolation is the process of using points with known values or sample points to estimate values at other unknown points. It can be used to predict unknown values for any geographic point data, such as elevation, rainfall, chemical concentrations, noise levels, and so on. Interpolation is a process of finding a formula (often a polynomial) whose graph will pass through a given set of points (x, y).

As an example, consider defining

$$x_0 = 0,\ x_1 = \pi/4,\ x_2 = \pi/2 \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.1.1)$$

and

$$y_i = \cos x_i ,\ i = 0, 1,2$$

This gives us the three points

$$(0, 1), (\pi/4, 1/\text{sqrt}(2)), (\pi/2, 0) \ldots\ldots\ldots\ldots \quad (2.1.2)$$

Now find a quadratic polynomial

$$P(x) = a^0 + a^1 x + a^2 (x)^2$$

for which

$$P(x_i) = y_i ,\ i = 0, 1, 2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.1.3)$$

2.2 Interpolation Surface in GIS Spatial Analyst

In addition to supplying tools for spatial analysis (i.e., for modeling suitability, distance, or hydrology), the GIS spatial analyst extension provides tools for spatial data analysis that apply statistical theory and techniques to the modeling of spatially referenced data. Elevation is a type of data that can be represented by surfaces. Each raster cell represents a measurement such as to fixed point or specific concentration level. Because obtaining values for each cell in a raster is typically not practical, sample points are used to derive the intervening values using the interpolation tools in GIS spatial analyst.

GIS is all about spatial data and the tools for managing, compiling, and analyzing that data. GIS spatial analyst extension provides a toolset for analyzing and modeling data. A set of sample points representing changes in landscape, population, or environment can be used to visualize the continuity and variability of observed data across a surface through the use of interpolation tools.The morphology and characteristics of these changes can be described.The ability to create surfaces from sample data makes interpolation both powerful and useful.

2.3 Interpolation Methods

The differences in the methods used for surface representation need to be discussed. Each representation is useful for specific situations.

A grid is a spatial data structure that defines space as an array of cells of equal sizes that are arranged in rows and columns. It represents a surface, each cell contain an attribute value that represents a change in Z value. The location of the cell in geographic space is obtained from its position relative to the origin grid. GIS spatial analyst offers several interpolation tools for generating surface grids from point data and these are discussed in the coming paragraphs.

2.3.1 Kriging

Kriging is a geostatistical interpolation technique that considers both the distance and the degree of variation between known data points when estimating values in unknown areas. A kriged estimate is a weighted linear combination of the known sample values around the point to be estimated.

Kriging assumes that the distance or direction between sample points reflects a spatial correlation that can be used to explain variation in the surface. The Kriging tool fits a mathematical function to a specified number of points, or all points within a specified radius, to determine the output value for each location. Kriging is a multistep process; it includes exploratory statistical analysis of the data, variogram modeling, creating the surface, and (optionally) exploring a variance surface. Kriging is most appropriate when you know there is a spatially correlated distance or directional bias in the data. It is often used in soil science and geology.

2.3.2 Inverse Distance Weighting (IDW)

The Inverse Distance Weighting interpolator assumes that each input point has a local influence that diminishes with distance. It weights the points closer to the processing cell greater than those further away. A specified number of points or all points within a specified radius can be used to determine the output value of each location. Use of this method assumes the variable being mapped decreases in influence with distance from its sampled location.

2.3.3 Natural Neighbour Inverse Distance Weighting (NNIDW)

Natural neighbor interpolation has many positive features. It can be used for both interpolation and extrapolation, and generally works well with clustered scatter points. Another weighted-average method, the basic equation used in natural neighbor interpolation is identical to the one used in IDW interpolation. This method can efficiently handle large input point datasets. When using the Natural Neighbor method, local coordinates define the amount of influence any scatter point will have on output cells.

The Natural Neighbour method is a geometric estimation technique that uses natural neighbourhood regions generated around each point in the data set.

Like IDW, this interpolation method is a weighted-average interpolation method. However, instead of finding an interpolated point's value using all of the input points weighted by their distance, Natural Neighbors interpolation creates a Delaunay Triangulation of the input points and selects the closest nodes that form a convex hull around the interpolation point, then weights their values by proportionate area. This method is most appropriate where sample data points are distributed with uneven density. It is a good general-purpose interpolation technique and has the advantage that you do not have to specify parameters such as radius, number of neighbours or weights.

2.3.4 Point Interpolation

A method that is similar to IDW, the Point Interpolation function allows more control over the sampling neighborhood. The influence of a particular sample on the interpolated grid cell value depends on whether the sample point is in the cell's neighborhood and how far from the cell being interpolated it is located. Points outside the neighborhood have no influence.

The weighted value of points inside the neighborhood is calculated using an inverse distance weighted interpolation or inverse exponential distance interpolation. This method interpolates a raster using point features but allows for different types of neighborhoods. Neighborhoods can have shapes such as circles, rectangles, irregular polygons, annuluses, or wedges.

2.3.5 Spline

Conceptually, it is analogous to bending a sheet of rubber to pass through known points while minimizing the total curvature of the surface. It fits a mathematical function to a specified number of nearest input points while passing through the sample points. This method is best for gently varying surfaces, such as elevation, water table heights, or pollution concentrations.

There are two spline methods: regularized and tension.

A Regularized method creates a smooth, gradually changing surface with values that may lie outside the sample data range. It incorporates the first derivative (slope), second derivative (rate of change in slope), and third derivative (rate of change in the second derivative) into its minimization calculations.

Although a Tension spline uses only first and second derivatives, it includes more points in the Spline calculations, which usually creates smoother surfaces but increases computation time.

This method pulls a surface over the acquired points resulting in a stretched effect.

In regularized spline the higher the weight, the smoother the surface. Weights between 0 and 0.5 are suitable. Typical values are 0, 0.001, 0.01, 0.1, and 0.5

In tension spline the higher the weight, the coarser the surface and more the values conform to the range of sample data. Weight values must be greater than or equal to zero. Typical values are 0, 1, 5, and 10.

2.3.6 Trend

Trend is a statistical method that finds the surface that fits the sample points using a least-square regression fit. It fits one polynomial equation to the entire surface. This results in a surface that minimizes surface variance in relation to the input values. The surface is constructed so that for every input point, the total of the differences between the actual values and the estimated values is a minimum (i.e., the variance will be as small as possible).

2.3.7 Topo to raster

Topo to Raster is a specialized tool for creating hydrologically correct raster surfaces from vector data of terrain components such as elevation points, contour lines, stream lines, lake polygons, sink points, and study area boundary polygons.

2.3.8 Density

Density tools (available in ArcGIS) produce a surface that represents how much or how many of something there are per unit area. Density tool is useful to create density surfaces to represent the distribution of a wildlife population from a set of observations, or the degree of urbanization of an area based on the density of roads.

CHAPTER THREE

DATA COLLECTION AND PROCESSING

3.1 Study area

The study area falls on the eastern part of Abudelike, north east of Khartoum with coordinates (X=643485.845, Y=1780429.109)m for upper left corner and (X=605584.207, Y= 1747686.856)m for lower right corner. there is no population in the study area and it is used for seasonal agriculture. it is somewhat flat and there is no clear variation in features except Wade Elhwade as shown in figure (3.1).

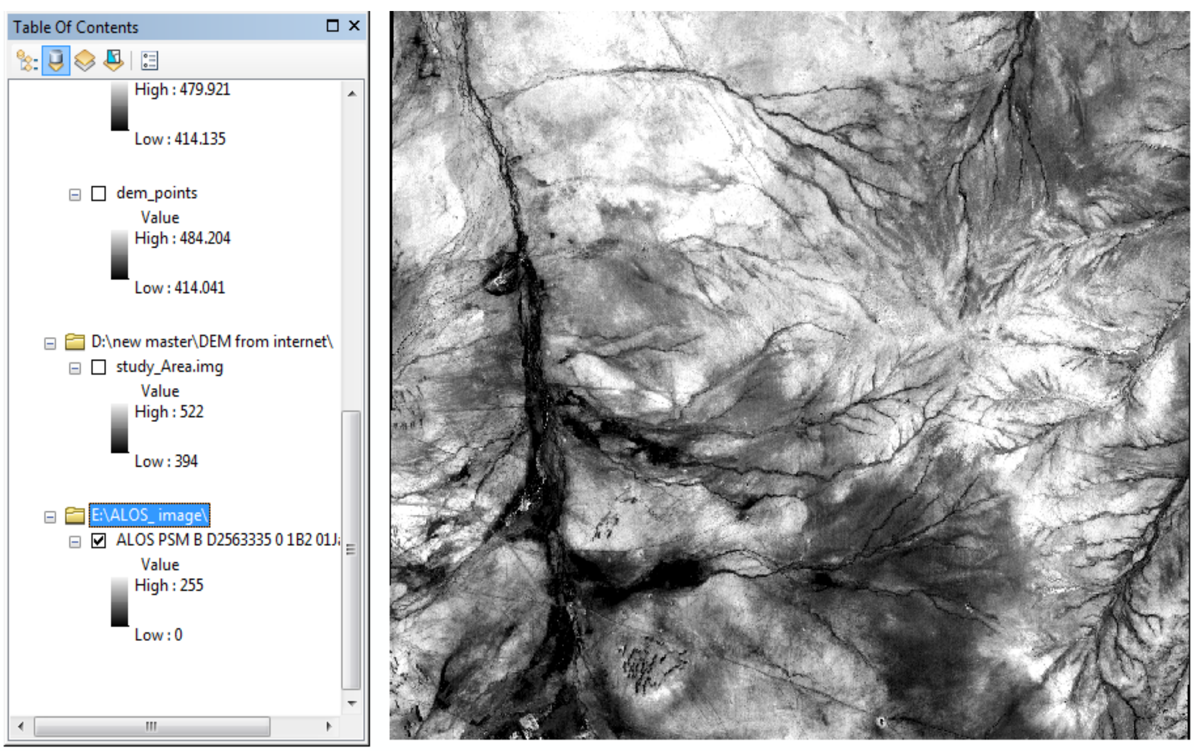


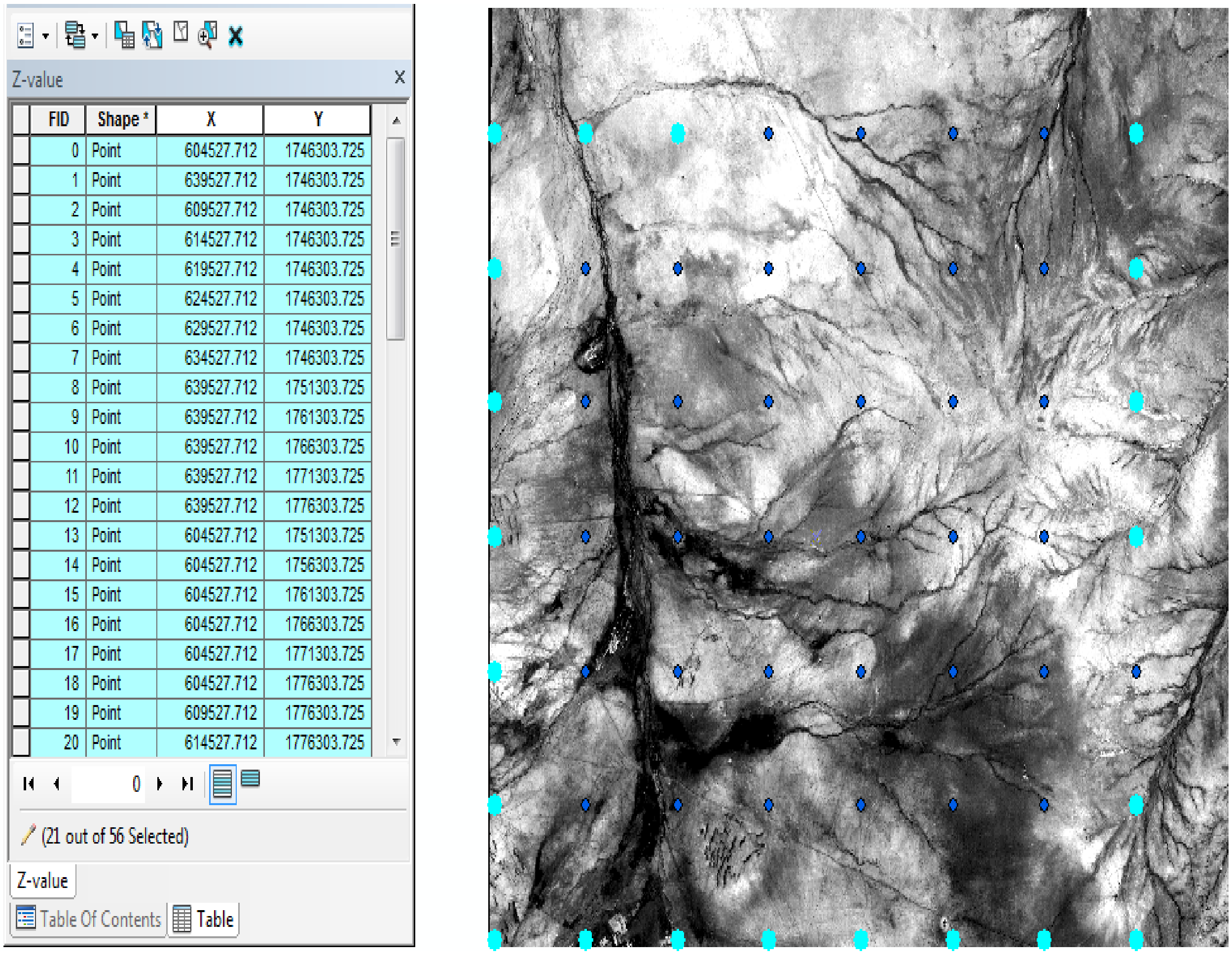
Figure (3.1) ALOS Satellite image for the study area

3.2 Methodology

Different procedures were done to test accuracy of elevations and Digital Elevation Models (DEMs) that procedures depend on Digital Elevation Model from ASTER and Arc GIS functions are used to make grid of the study area, Extractions and interpolations:

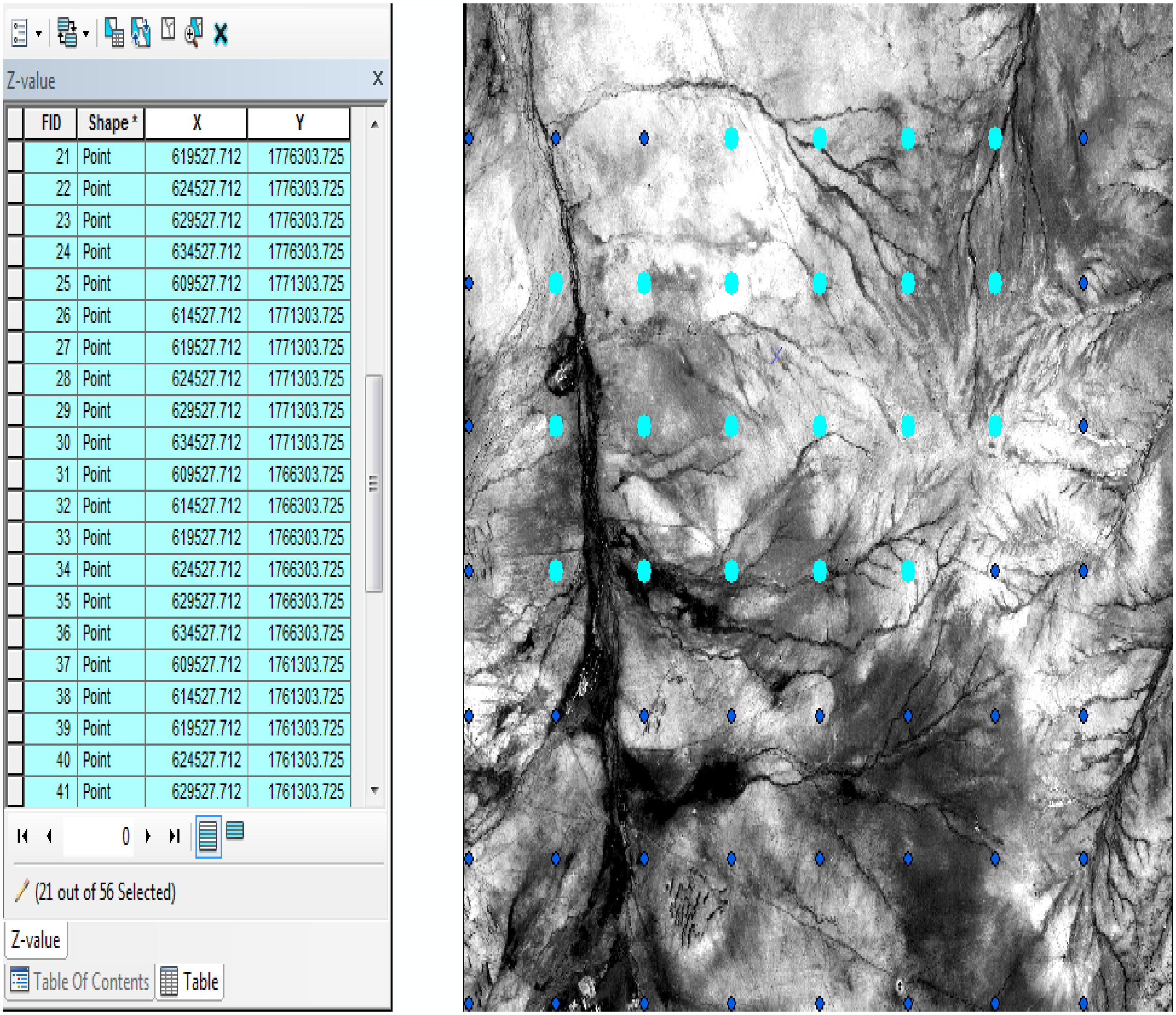
3.2.1 Structure of grid

A gridconsisting of 56points with 8collums and 7rows was built with each point having two dimensional coordinates(X, Y) as in Figure (3.2).



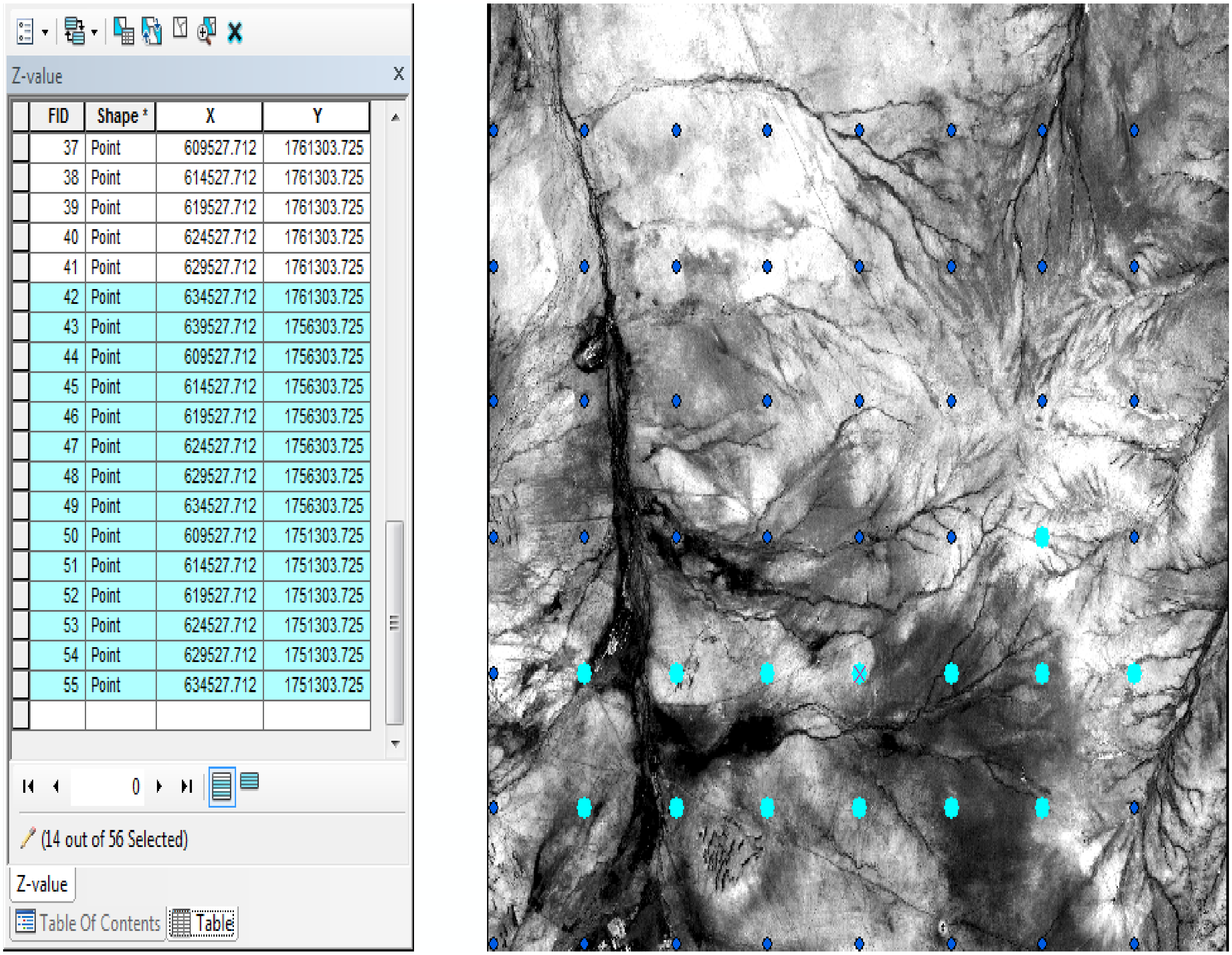
FID	Shape *	X	Y
0	Point	604527.712	1746303.725
1	Point	639527.712	1746303.725
2	Point	609527.712	1746303.725
3	Point	614527.712	1746303.725
4	Point	619527.712	1746303.725
5	Point	624527.712	1746303.725
6	Point	629527.712	1746303.725
7	Point	634527.712	1746303.725
8	Point	639527.712	1751303.725
9	Point	639527.712	1761303.725
10	Point	639527.712	1766303.725
11	Point	639527.712	1771303.725
12	Point	639527.712	1776303.725
13	Point	604527.712	1751303.725
14	Point	604527.712	1756303.725
15	Point	604527.712	1761303.725
16	Point	604527.712	1766303.725
17	Point	604527.712	1771303.725
18	Point	604527.712	1776303.725
19	Point	609527.712	1776303.725
20	Point	614527.712	1776303.725

Figure (3.2) Grid formation



FID	Shape *	X	Y
21	Point	619527.712	1776303.725
22	Point	624527.712	1776303.725
23	Point	629527.712	1776303.725
24	Point	634527.712	1776303.725
25	Point	609527.712	1771303.725
26	Point	614527.712	1771303.725
27	Point	619527.712	1771303.725
28	Point	624527.712	1771303.725
29	Point	629527.712	1771303.725
30	Point	634527.712	1771303.725
31	Point	609527.712	1766303.725
32	Point	614527.712	1766303.725
33	Point	619527.712	1766303.725
34	Point	624527.712	1766303.725
35	Point	629527.712	1766303.725
36	Point	634527.712	1766303.725
37	Point	609527.712	1761303.725
38	Point	614527.712	1761303.725
39	Point	619527.712	1761303.725
40	Point	624527.712	1761303.725
41	Point	629527.712	1761303.725

Figure (3.2) Grid formation continue



FID	Shape *	X	Y
37	Point	609527.712	1761303.725
38	Point	614527.712	1761303.725
39	Point	619527.712	1761303.725
40	Point	624527.712	1761303.725
41	Point	629527.712	1761303.725
42	Point	634527.712	1761303.725
43	Point	639527.712	1756303.725
44	Point	609527.712	1756303.725
45	Point	614527.712	1756303.725
46	Point	619527.712	1756303.725
47	Point	624527.712	1756303.725
48	Point	629527.712	1756303.725
49	Point	634527.712	1756303.725
50	Point	609527.712	1751303.725
51	Point	614527.712	1751303.725
52	Point	619527.712	1751303.725
53	Point	624527.712	1751303.725
54	Point	629527.712	1751303.725
55	Point	634527.712	1751303.725

Figure (3.2) Grid formation continue

3.2.2 Extraction of Elevations

The z values in Table (3.1) were extracted from DEM of the study area (Abudelike) with 30m resolution, as shown in Figure (3.3)

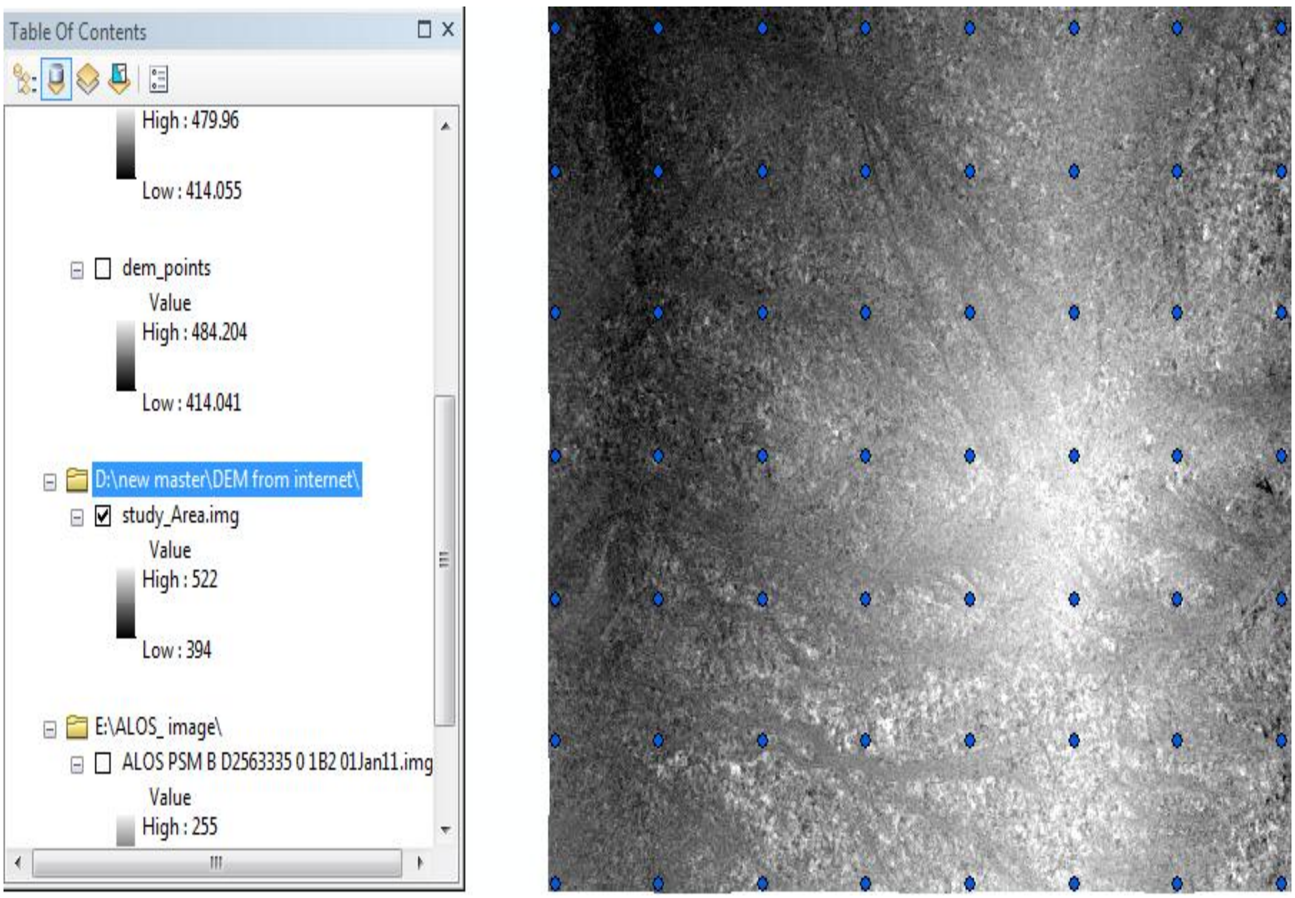


Figure (3.3) DEM formation

Table (3.1) Extracted Z values

Points	X (m)	Y (m)	Z (m)
1	604527.712	1776303.725	**415**
2	609527.712	1776303.725	**414**
3	614527.712	1776303.725	**424**
4	619527.712	1776303.725	**438**
5	624527.712	1776303.725	**443**
6	629527.712	1776303.725	**446**
7	634527.712	1776303.725	**443**
8	639527.712	1776303.725	**430**
9	604527.712	1771303.725	**427**
10	609527.712	1771303.725	**426**
11	614527.712	1771303.725	**438**
12	619527.712	1771303.725	**450**
13	624527.712	1771303.725	**449**
14	629527.712	1771303.725	**449**
15	634527.712	1771303.725	**441**
16	639527.712	1771303.725	**446**
17	604527.712	1776303.725	**425**
18	609527.712	1776303.725	**423**
19	614527.712	1766303.725	**429**
20	619527.712	1766303.725	**444**
21	624527.712	1766303.725	**453**

Table (3.1) Continue

No	X (m)	Y (m)	Z (m)
22	629527.712	1766303.725	**462**
23	634527.712	1766303.725	**468**
24	639527.712	1766303.725	**458**
25	604527.712	1761303.725	**435**
26	609527.712	1761303.725	**426**
27	614527.712	1761303.725	**449**
28	619527.712	1761303.725	**456**
29	624527.712	1761303.725	**471**
30	629527.712	1761303.725	**477**
31	634527.712	1761303.725	**465**
32	639527.712	1761303.725	**473**
33	604527.712	1756303.725	**427**
34	609527.712	1756303.725	**431**
45	614527.712	1756303.725	**445**
36	619527.712	1756303.725	**452**
37	624527.712	1756303.725	**483**
38	629527.712	1756303.725	**484**
39	634527.712	1756303.725	**458**
40	639527.712	1756303.725	**451**
41	604527.712	1751303.725	**439**
42	609527.712	1751303.725	**438**
43	614527.712	1751303.725	**443**

Table (3.1) Continue

No	X (m)	Y (m)	Z (m)
44	619527.712	1751303.725	**460**
45	624527.712	1751303.725	**469**
46	629527.712	1751303.725	**476**
47	634527.712	1751303.725	**464**
48	639527.712	1751303.725	**450**
49	604527.712	1746303.725	**442**
50	609527.712	1746303.725	**432**
51	614527.712	1746303.725	**462**
52	619527.712	1746303.725	**456**
53	624527.712	1746303.725	**480**
54	629527.712	1746303.725	**474**
55	634527.712	1746303.725	**452**
56	639527.712	1746303.725	**448**

3.2.3 DEM generated using 44 control points

12 points were eliminated from the grid and an interpolation was carried out, using Kriging method, to generate a DEM, as inFigures (3.4) and (3.5).

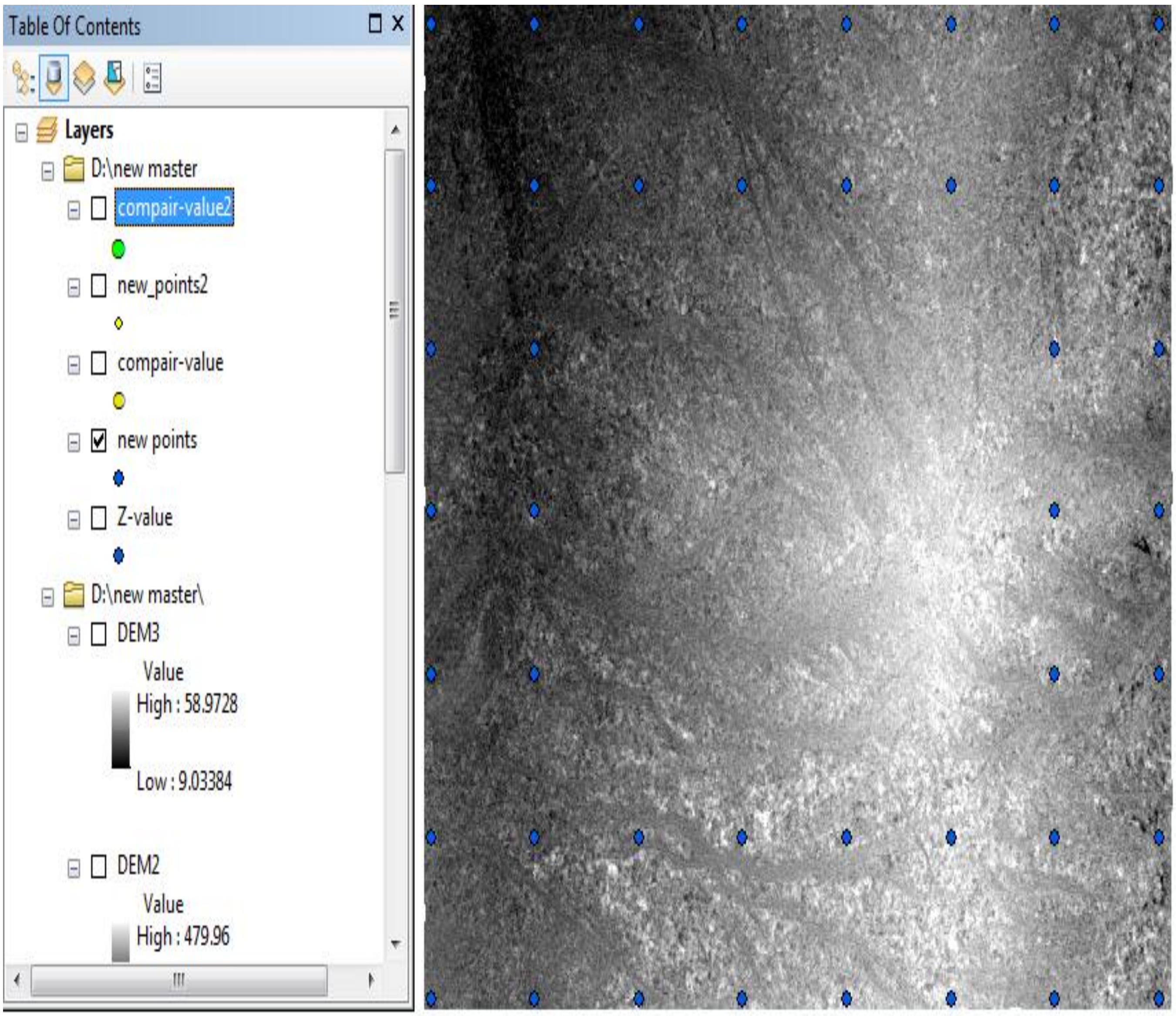


Figure (3.4) 44 points after elimination

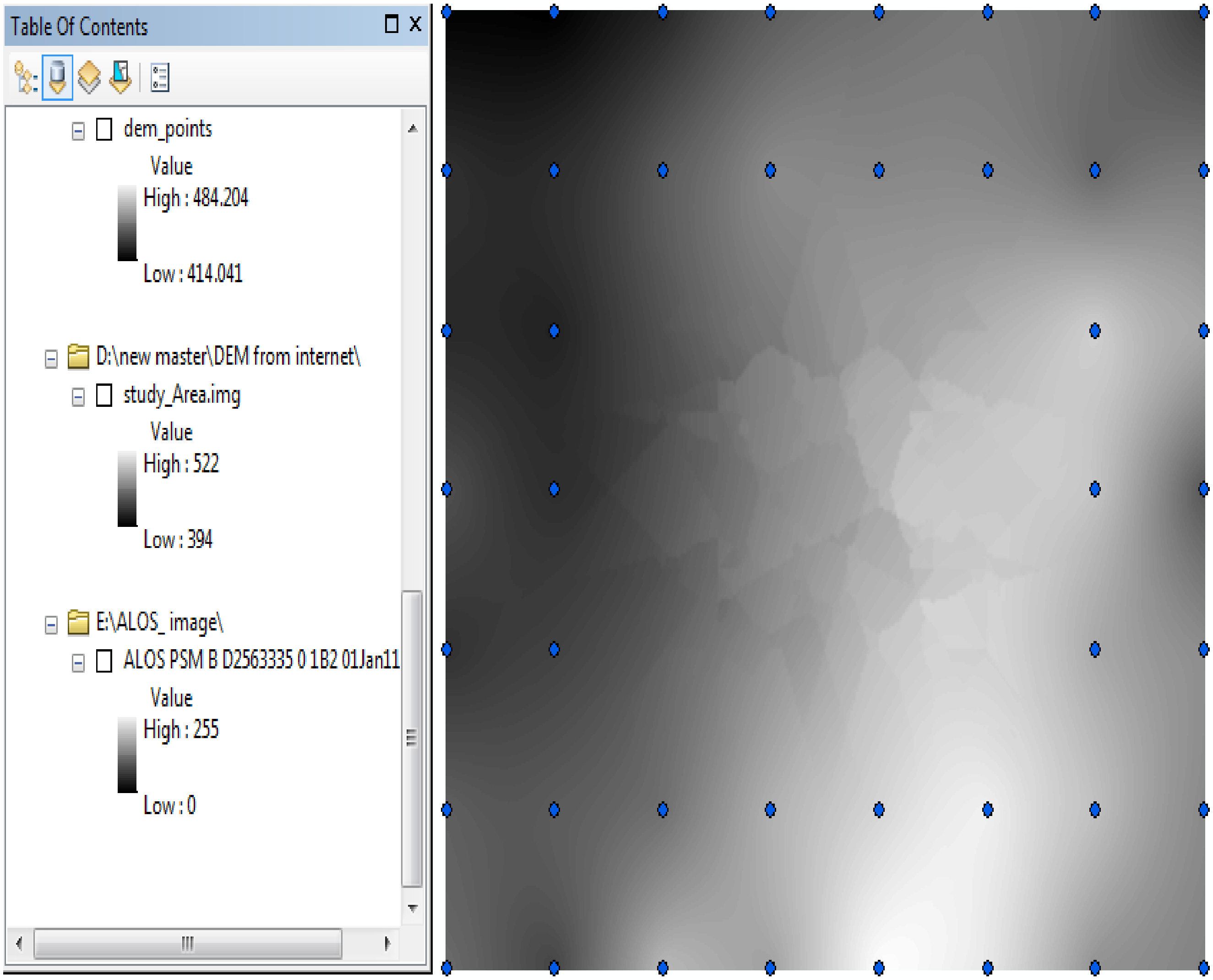


Figure (3.5) Interpolated 44points DEM

3.2.4 Extraction of eliminated 12 points and compared elevations

Z values in Table (3.1) of the 56 points were extracted and the differences between these values and their original DEM values were determined. These are shown in Figure (3.6).

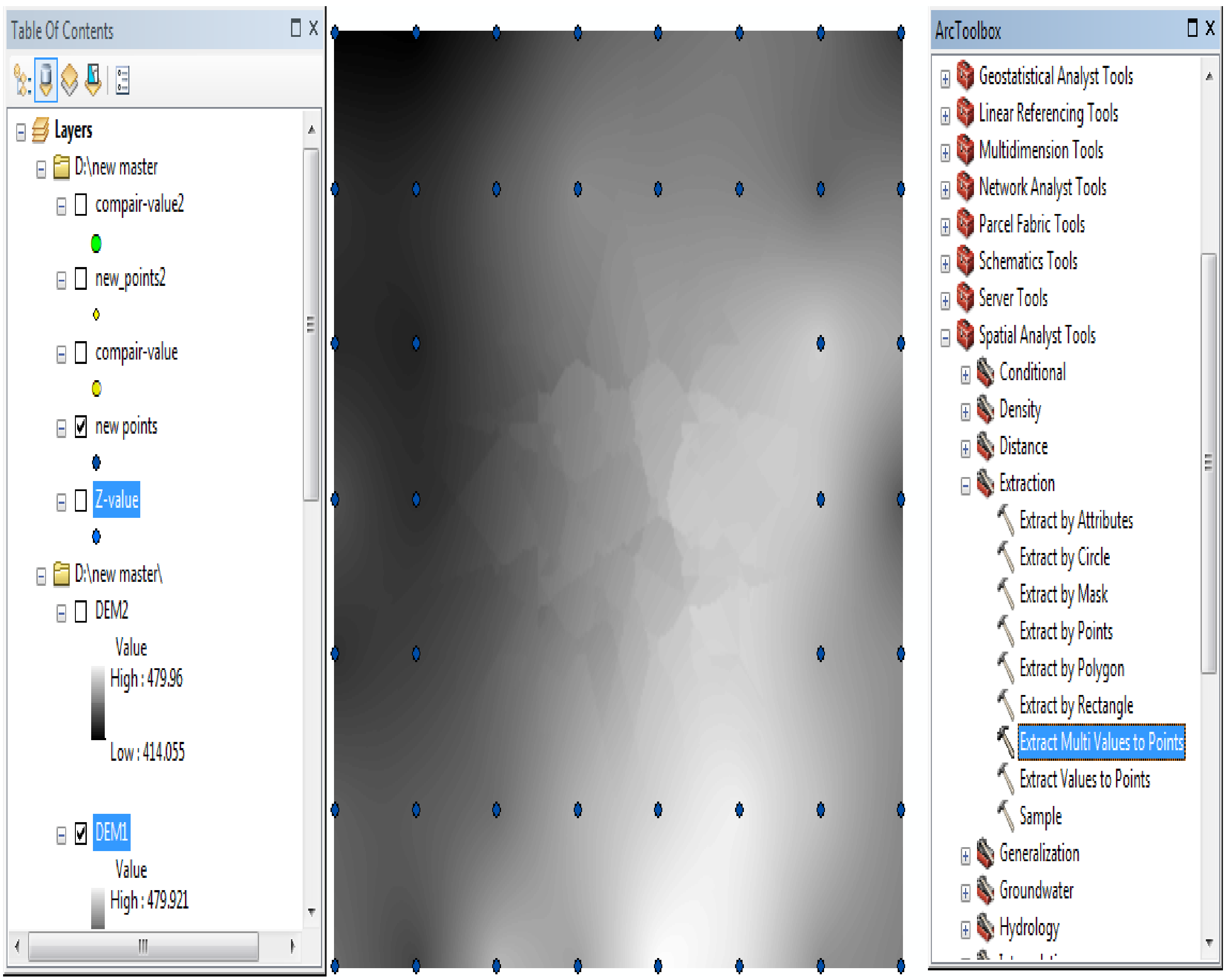
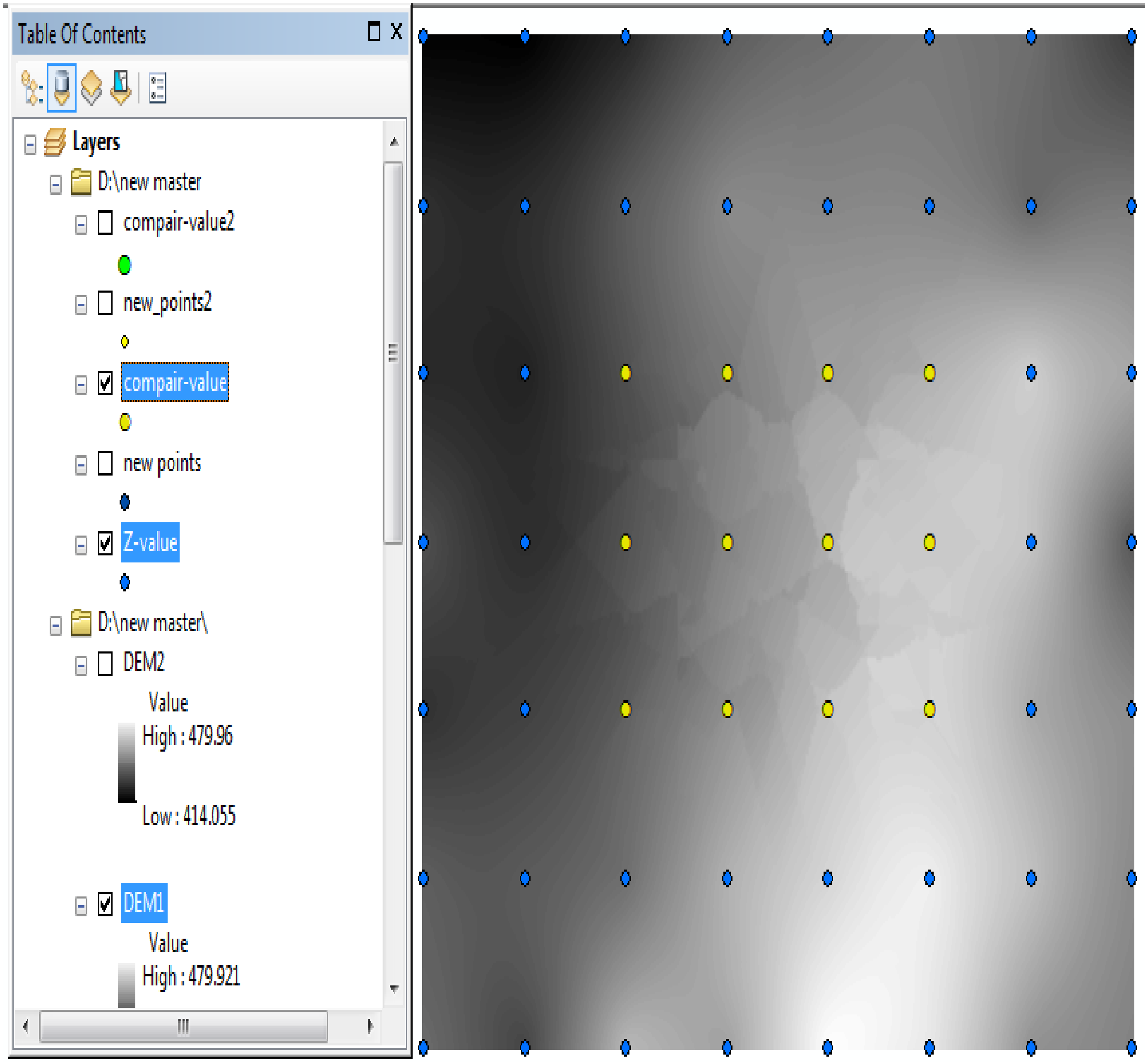


Figure (3.6) Extracted Z values from 44 points DEM

The differences in Z values of the 12 eliminated points shown in Figure (3.7) were extracted and found to be as in Table (3.2).

Table (3.2) Differences in Z values for the eliminated points

No	X (m)	Y (m)	Z values (m)	Z from Interpolated DEM (m)	Errors in Z (m)
1	614527.712	1766303.725	429	434.833	5.833
2	619527.712	1766303.725	444	445.388	1.388
3	624527.712	1766303.725	453	454.537	1.537
4	629527.712	1766303.725	462	458.688	3.312
5	614527.712	1761303.725	449	435.765	13.234
6	619527.712	1761303.725	456	448.637	7.363
7	624527.712	1761303.725	471	461.167	9.833
8	629527.712	1761303.725	477	466.533	10.467
9	614527.712	1756303.725	445	438.197	6.803
10	619527.712	1756303.725	452	452.088	0.088
11	624527.712	1756303.725	483	465.641	17.359
12	629527.712	1756303.725	484	467.797	16.203



Black points: Existing **White points: Eliminated**

Figure (3.7) Differences of 12 points

3.2.5 DEM generated using 36 control points

20 nodal points were eliminated from the grid and a new DEM constructed by interpolation as in Figure (3.8).

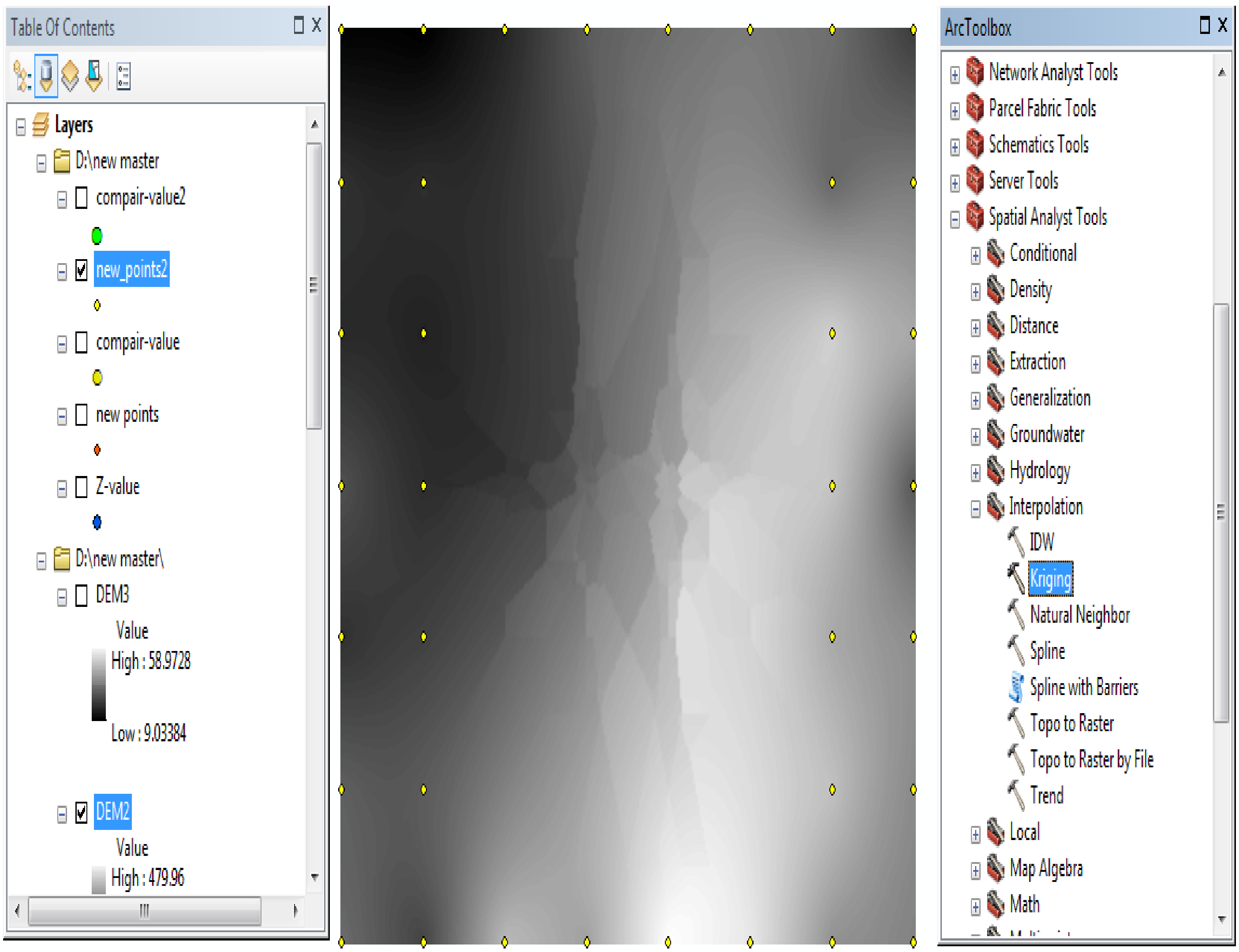


Figure (3.8) 36 points DEM

3.2.6 Extraction of elevations

The Z values of all points were extracted from the constructed DEM, as in Figures (3.9) and (3.6) together with the Z differences between those of the original values and those found in (3.2.5) were determinedas shown in Figure (3.10) and Table (3.3).

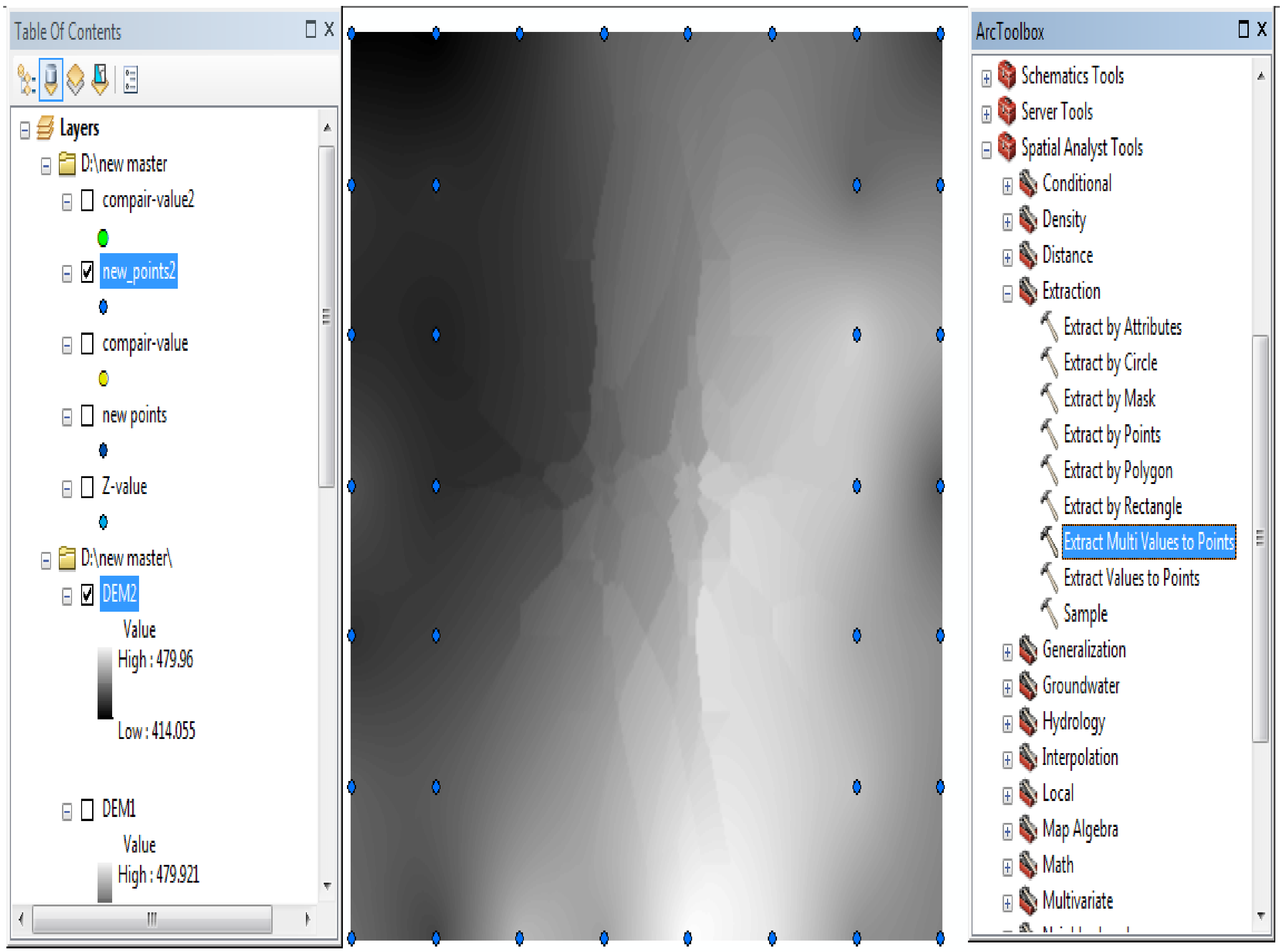
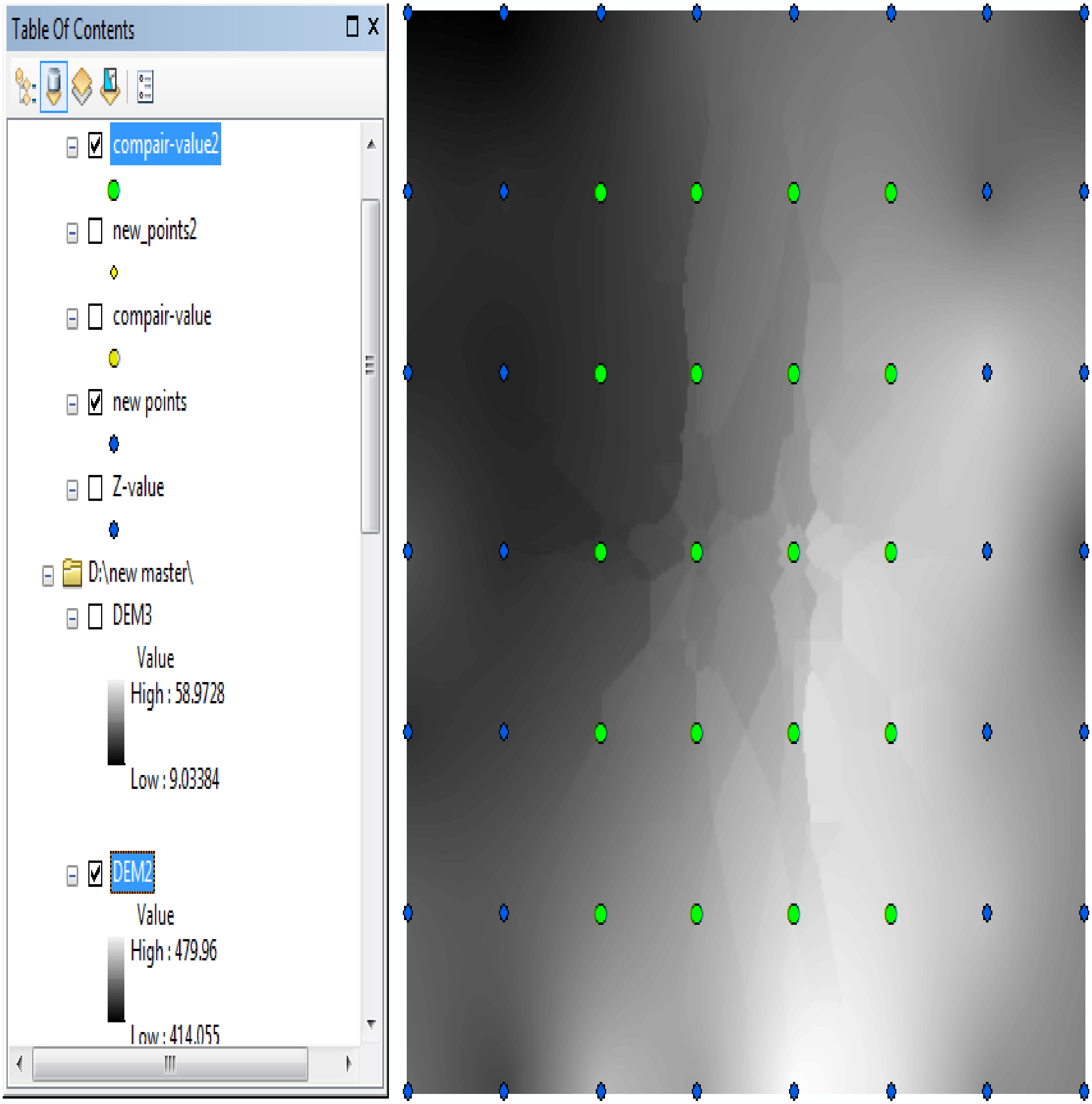


Figure (3.9) Extracted Z values from 36 points DEM

Table (3.3) Differences in Z values using 36 control points

No	X (m)	Y (m)	Z values (m)	Z from Interpolated DEM (m)	Errors (m)
1	614527.712	1771303.725	438	427.498	10.191
2	619527.712	1771303.725	450	437.870	12.040
3	624527.712	1771303.725	449	446.686	2.439
4	629527.712	1771303.725	449	450.452	1.283
5	614527.712	1766303.725	429	427.556	7.277
6	619527.712	1766303.725	444	439.801	5.587
7	624527.712	1766303.725	453	448.390	6.147
8	629527.712	1766303.725	462	460.644	1.956
9	614527.712	1761303.725	449	429.184	6.581
10	619527.712	1761303.725	456	441.969	6.668
11	624527.712	1761303.725	471	458.017	3.15
12	629527.712	1761303.725	477	467.385	0.852
13	614527.712	1756303.725	445	438.976	0.779
14	619527.712	1756303.725	452	449.867	2.221
15	624527.712	1756303.725	483	462.783	2.858
16	629527.712	1756303.725	484	468.982	1.185
17	614527.712	1751303.725	443	447.412	4.555
18	619527.712	1751303.725	460	456.808	3.0567
19	624527.712	1751303.725	469	469.806	0.551
20	629527.712	1751303.725	476	471.383	4.608



Black points: Existing **White points: Eliminated**

Figure (3.10) Differences of 20 points

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

The present study was an attempt to know about the accuracy of elevations extracted from interpolated digital elevation models (DEMs). As stated in the previous Chapter. It can be seen from Table (3.2) the maximum and minimum difference in Z values extracted from the interpolated DEM using 44 points DEM are approximately 17.4 and 0.1m.

The Root Mean Square of Error (RMSE) is found and it can be summation of square of errors over numbers of errors under square root. (RMSE) be approximately 10m.

From Table (3.3), it can be seen that the range of errors is about 11m (a maximum error of approximately 12m and a minimum error of approximately 1m). The RMSE is about 5m.

4.2 Discussion

From these results of section 4.1, it can be seen that there is no direct relation between number of control points used in interpolated DEM and the accuracy of elevations. However, there is an influence of control points that are near the extracted points longer than of these control points further away. also, the distributions of points have a direct effect on accuracy of heights extracted from a given DEM.

CHAPTER FIVE

CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

5.1 Conclusions

According to the procedures and results obtained in Chapter four it can be concluded that:

1. Interpolation can be easily represented a surface and generated Digital Elevation Models (DEMs) from even number of points.
2. Accuracy of Digital Elevation Models (DEMs) depends on accuracy of elevations and distribution of points.
3. The main points give accuracy of (DEM) there are on the edges of grid.

5.2 Suggestions for Future Work

The following are the recommended for future work:

1. Testing the accuracy of elevations and (DEMs) using the different methods of interpolation.
2. Interpolating DEMs with systematic elimination of control points.

REFERENCES

1. Burrough and McDonnell, 1998
2. Carrara et al, 1997
3. Stocks and Heywood, 1994
4. ASTER GDEM Validation Team. 2009
5. ASTER global DEM validation summary report.
6. map & Data Library , University of Toronto

Web sites:

1. http://earthexplorer.usgs.gov
2. http://mdl.library.utoronto.ca

APPENDICES

Appendix A:

Extracted Elevations by meters

Z-value

	FID	Shape *	RASTERVALU
	0	Point	442
	1	Point	448
	2	Point	432
	3	Point	462
	4	Point	456
	5	Point	480
	6	Point	474
	7	Point	452
	8	Point	450
	9	Point	437
	10	Point	458
	11	Point	446
	12	Point	430
	13	Point	439
	14	Point	427
	15	Point	435
	16	Point	425
	17	Point	427
	18	Point	415
	19	Point	414
	20	Point	424
	21	Point	438
	22	Point	443

Extracted Elevations

	FID	Shape	RASTERVALUE (m)
	23	Point	446
	24	Point	443
	25	Point	426
	26	Point	438
	27	Point	450
	28	Point	449
	29	Point	449
	30	Point	441
	31	Point	423
	32	Point	429
	33	Point	444
	34	Point	453
	35	Point	462
	36	Point	468
	37	Point	426
	38	Point	449
	39	Point	456
	40	Point	471
	41	Point	477
	42	Point	465
	43	Point	451
	44	Point	431
	45	Point	445

Extracted Elevations

	FID	Shape	RASTERVALUE (m)
	46	Point	452
	47	Point	483
	48	Point	484
	49	Point	458
	50	Point	438
	51	Point	443
	52	Point	460
	53	Point	469
	54	Point	476
	55	Point	464

Errors of 12 Extracted points by meters

Table

compair-value

FID	RAST	DEM1	Differ
0	429	434.833	5.8330
1	444	445.388	1.388
2	453	454.537	1.5369
3	462	458.688	3.3120
4	449	435.765	13.234
5	456	448.637	7.3630
6	471	461.167	9.8330
7	477	466.533	10.467
8	445	438.197	6.8030
9	452	452.088	0.0880
10	483	465.641	17.359
11	484	467.797	16.203

Errors of 20 extracted points by meters

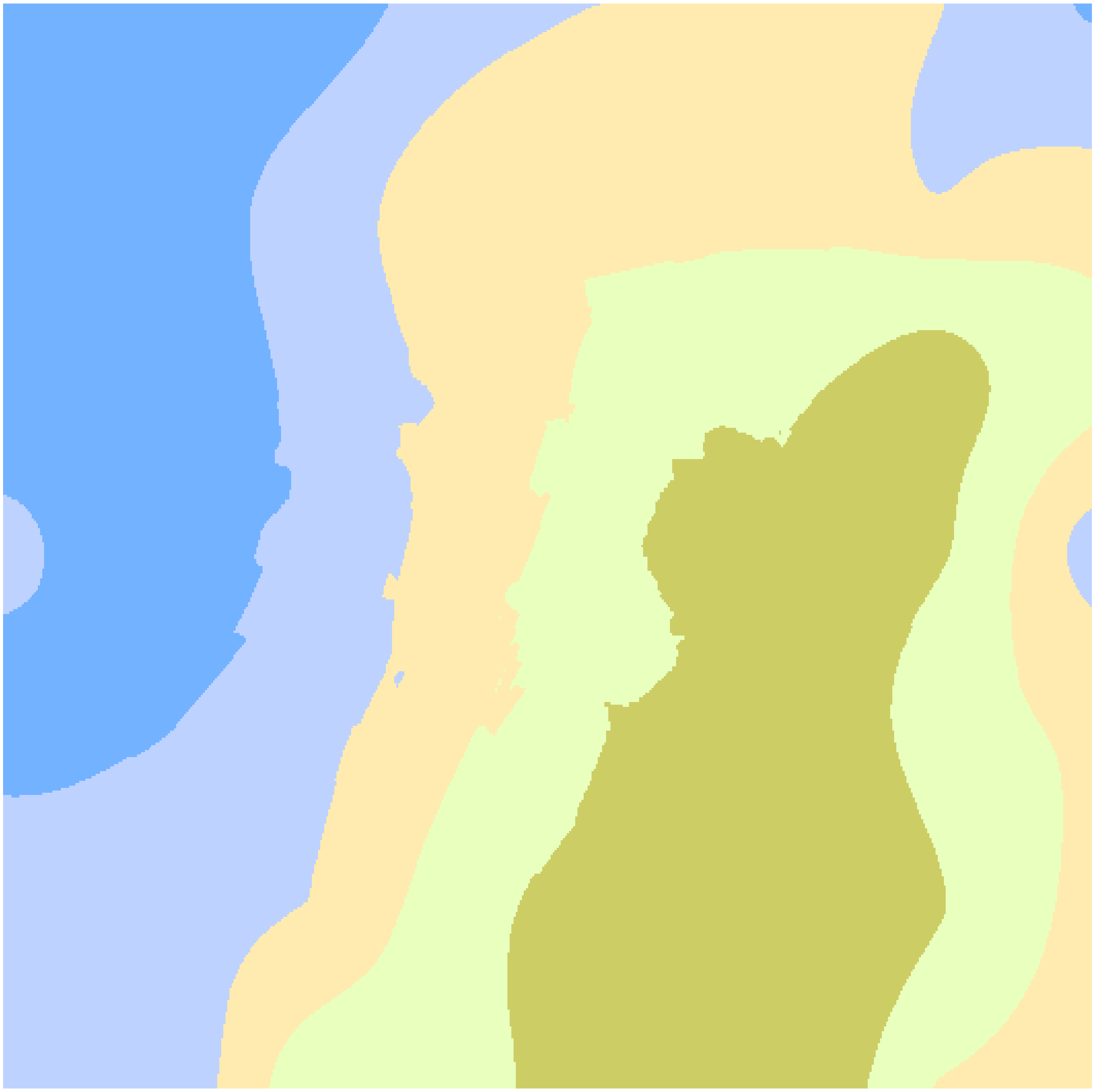
Table

compair-value2

FI	Sha	RAST	DEM2	Difrents
0	Point	438	427.498	10.19101
1	Point	450	437.87	12.040009
2	Point	449	446.686	2.438995
3	Point	449	450.452	1.28299
4	Point	429	427.556	7.277008
5	Point	444	439.801	5.587006
6	Point	453	448.39	6.146973
7	Point	462	460.644	1.956024
8	Point	449	429.184	6.581024
9	Point	456	441.969	6.667999
10	Point	471	458.017	3.149994
11	Point	477	467.385	0.85202
12	Point	445	438.976	0.779022
13	Point	452	449.867	2.221008
14	Point	483	462.783	2.858002
15	Point	484	468.982	1.184998
16	Point	443	447.412	4.554993
17	Point	460	456.808	3.056976
18	Point	469	469.806	0.550995
19	Point	476	471.383	4.608002

Appendix B:

DEM with 44 points



DEM with 36 points