بسم الله الرحمن الرحيم

Sudan University of Science & Technology

College of Graduate Studies

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in

RS&GIS

Research about:

Evaluation of Heights Interpolation Methods Using Geographical Information Systems

تقييم الارتفاعات بطرق الاستكمال باستخدام نظم المعلومات (الجغرافيه)

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بسم الله الرحمن الرحيم

الآية

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Acknowledgments

Forallwhomare in human freedom. To that which a great being and alsoto science researcher,who sit too long and research more. For who lovescience, for all remover of ignorance, and all my teachers learn me whatmean the life, and my supervisor who stand beside me as the guider andcollaborator,I learn fromhim the kindness before the science,I would like to thank Dr. Msaad Khalid for his continuessupport and for guiding me throughout the whole project.And also to my parents, and my wifeand my children, and also to those whom are prayers me to success. Mydeepest appreciations to the family of surveying school of Sudan University of Science and Technology.

My regard

Researcher

المستخلص

سطح الجويد هو السطح الذي يكافي متوسط سطح البحر, وهذا البحث يركز علي تقنية استخراج نماذج التضاريس الرقميه مستند علي تقنيات طرق الاستكمال البيني اعتمادا علي النقاط المرجعيه التي تم جمعها من الحقل من متوسط مستوي سطح البحر. وهنالك معادلات عديده تستخدم لاستخراج نموذج التضاريس الرقمي من النقاط المقاسه.

الهدف الرئيسي هو تقييم ارتفاعات النقاط من نموذج التضاريس الرقمي باستخدام سطحيين مختلفين سطح مستوي واخر مختلف التضاريس. هذا البحث يركز علي ثلاثه من طرق الاستكمال البيني (الكريغنغ، الجار الاقرب، معكوس المسافه) في نظم المعلومات الجغرافيه لاستخلاص القيم المجهوله من قيم النقاط المعلومه.

النتائج لي هذه الدراسه اظهرت فاعليه ودقه عاليه لطرق الاستكمال البيني مقارنة مع الطرق التقليديه خاصة في المناطق المتماثله التضاريس، وقيمت النتائج بواسطة الطرق الاحصائيهالمختلفه (الانحراف المعياري وخطا متوسط الجزر التربيعي).

طريقة الكريغنغ هي الافضل في السطحيين حيث اظهرت دقه عاليه في السطح المتشابه.

Abstract

The geoid is an equipotential surface which coincides on the average with the mean sea level has significant relevance in geodesy, surveying and other earth related disciplines.This thesis focuses on the digital terrain modeling (DTM) technique based on geometrical interpolation approach by fitting a surface that depends on the reference points that are chosen in the critical and characteristic locations of the field to represent the trend of the surface. Using the orthometric heights for all the points were computed.A multiple regression model was formulated as the required geometrical model to further adjust the derived (DTMS) from observation.

The main objective is to evaluate heights interpolation methods, and create a digital terrain models (DTMs) of base types of relief in two study areas (flatlands, hilly areas). This research focuses on the application of three interpolation methods (Kriging, Natural Neighborand Inverse distance weights) in geographical information system (GIS) to estimate the unknown value from the digital terrain models. Results from this study show the interpolation using GIS techniques is effective and has a higher level of accuracy compared to conventional methods, especially in the areas with similar terrain, based on statistic methods (standard deviation and Root Mean Square Error). Kriging method enable to determine an appropriate estimated elevation in unknown altitude regions, in the study area (A) where variations in the terrain are noticeable the accuracy is low, in the study area (B) where the topography is similar the accuracy is high.

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CHAPTER ONE

Introduction

1.1 Literature Reviews

On 2011 similar study was done in Technical University of Madrid, Madrid 28040, Spain. The title is Comparison of interpolation methods for the study of forest variables using a Geographic Information System.Inthese paper forest data variables as tree height anddiameter measured in two plots in Central Mountains in Spain. These data were georeferenced to obtain maps that can visualize the spatial variability ofthese forest variables. In order to evaluate the best interpolation method thatcould adequately explain the spatial variability of those variables, twointerpolation methods were studied: inverse distance weighted (IDW) and Ordinary Kriging (OK). A comparison of results was made by means ofstatistical methods to analyze residuals. Results with the kriging method were slightly better. {1}.

In other study on 2013 the title is Comparison of the interpolation methods on digital terrain models, in this study we focused on the interpolation methods for different terrain surface on the accuracy of interpolated heights. In this study, comparisons were performed between Inverse Distance Weighted (IDW) and Radial Basis Functions (RBFs) to test their performances on different terrain surface such as mountainous, flat and real-world. A comprehensive comparison was also implemented not only on the aspect of Root Mean Square Error (RMSE), the results obtained in this study allow us to observe the quality of the interpolation on DTM is related to such variables as terrain ruggedness and interpolation method, which can help us choose a appropriate interpolation method in order to obtain a good quality in the interpolation applied in digital terrain modeling. {2}.

On 2012 similar study was done the title is Quality test of interpolation methods on steepness regions for the use in surface modeling, by Nursu

Tunalıoğlu**.** Digital elevation models, which have significant importance for all kinds of planning, construction work, visualization, mapping, etc...This study reveals that a comparison ofthe interpolation methods withterrainmodeling procedure should be considered in order to determinethevalidity of the models classified by the terrainmorphology. Results indicate that interpolation methods such as Kriging and RBF give moreeffective solutionswhere the heights change suddenly and significantly, but if the height differences are relatively lower in the studyarea, thestandard deviations give similar solutions withrespect to each interpolation methods. {3}.

1.2 Problem Statement

In the last years, the analysis and interpretation of spatial datasets became an important topic in Geostatistics. In the past, this process was highly human dependent and individuals would take different approaches, this lead to large distinct different solutions. Geographic information systems (GIS) have emerged as widely used software system for input, storage, manipulation and output of geographically referenced data over the years. A set of sample points representing change in the environment, landscape, or population can be used to visualize the continuity and variability of observed data across surface using interpolation tools. Apowerful collection of tools is provided by the geographical information systems for the management, collection, and analysis of spatial data. The Arc GIS geostatistical analyst tool which can be used for spatial data exploration and surface from data measurement is used for this study.The aim of the thesis is to evaluate the interpolation techniques andestimate the values at locations, where measured values are not available. Spatial interpolation is widely used for creating continuous data collected at discrete location.

1.3 The Objectives

The thesis is divided into three main objectivesto evaluate the interpolation techniques depending on the type of surface, comparison between three interpolation methods and assess the accuracy and effectiveness of surfaces produced with Kriging, Natural Neighbor (NB), and Inverse distance weighted (IDW) interpolation methods.

1.4 Related Topics

Many studies are similar this study like, Evaluation of five GIS Based interpolation techniques for estimating the radon concentration for unmeasured zip codes in the state of Ohio by Suman Maroju in the University of Toledo.

Other one in Technical University of Madrid, Spain. The title is Comparison of interpolation methods for the study of forest variables using a Geographic Information System.

Other one the Comparison of the interpolation methods on digital terrain models Digital terrain models (DTM) have been used in many applications since they came into application in the late 1950s.

1.5 Lay out

With respect to the gold of our study, the whole work has been organized with the following structure, chapter one includes a literature review, problem statement, objectives of research, related topics and lay out, chapter two include definition Digital Terrain Model (DTM) and resource, in chapter three definition interpolation methods in Arc GIS will be describe, chapter four for methodology, chapter five show the results and chapter six hold on conclusions and recommendations.

CHAPTER TWO
Digital Terrain Models

2.1 Introduction

A model of the terrain surface is often a necessary requirement in identifying, analyzing and mitigating problems in many fields including hydrology, geomorphology, and environmental modeling, to present the terrain surface, the Digital Terrain Model (DTM), has been one of the most important concepts with the development of computing technology, modern mathematics, and computer graphics, the digital terrain model is simply a statistical representation of the continuous surface of the ground by a large number of selected points with known X, Y, Z coordinates in an arbitrary coordinate field.

Digital Terrain Models have found wide applications in various disciplines such as mapping, remote sensing, civil engineering, Mining engineering, geology, geomorphology, military engineering, land planning, and communications. Today several technique s are available for generating elevation data such asSynthetic Aperture Radar (SAR) remote sensing, photogrammetric techniques and airborne laser scanning as a powerful technology for automated elevation data collecting from the Earth's surface.

Built-up and forested areas, however, need automated filtering and classification for separating terrain and off- terrain regions in order to generate DTMs. The filtering procedure is to distinguish between points which belong to the elevation objects, and those that belong to the bare earth. Filtering is an important procedure, because the quality of filtered points has a direct impact on the quality of the DTM. In other words errors in the filtered points lead to the production of a false digital terrain model. However, all of these corresponding techniques to generate DTM imply random, systematic and gross errors and thus, including inherent errors so it is difficult to achieve the desirable precision in interested applications. Consequently, some procedures or methodologies for quality management and control of the DTMs are required. In this manner, several methods have been developed to assess the quality of produced DTMs. Root Mean Square Error (RMSE) is the most common way to quantify the difference between the generated DTM and ground truth. Additionally other statistical parameters such as arithmetic mean of height differences, terrain slope, standard deviation, covariant function for heights, autocorrelation analysis, as well as enhanced visual techniques can be utilized for quality assessment.

The accuracy of a DTM is a result of many individual factors, which are:

1. Attributes of the source data as accuracy, density, and distribution.
2. Characteristics of the terrain.
3. The methods used for the construction of DTM surface, i.e DTM generation algorithms and interpolation techniques.

2.2 Data Sources for Digital Terrain Models:

For terrain surfaces with different type of coverage, different measurement techniques for data acquisition may be used. However to chose the effective technique, tradeoff between accuracy and production cost always has to be considered. The cost for generating DTMs can become significant for increased resolution, accuracy, and especially number of elevation points.

Figure**2.1** shows a comparison of the cost of producing 1km^2 against the accuracy of the different data acquisition techniques

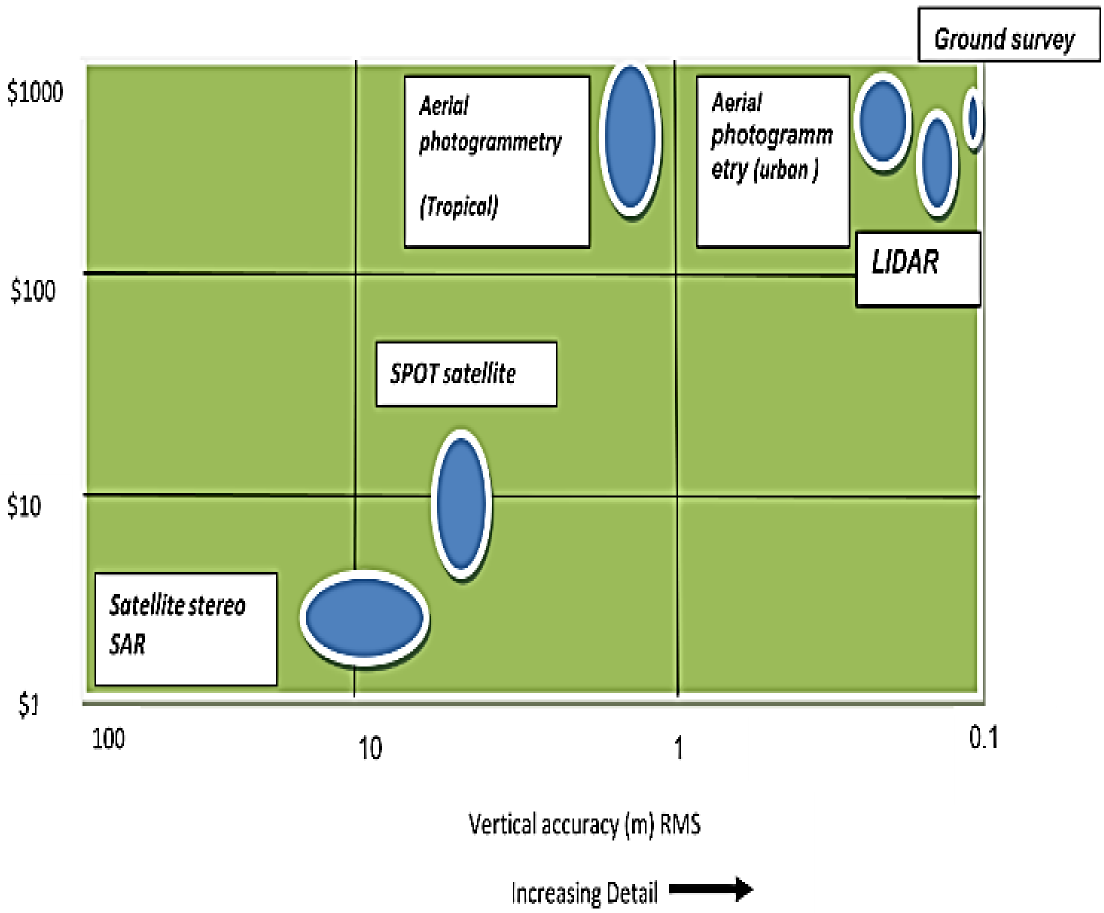

Figure **2.1** cost of different data acquisition techniques.

2.2.1Ground Survey

Surveydata may be input directly into computer systems through data recorders which may be coupled to field instruments. Since ground survey data tend to be very accurate and surveyors tend to adapt the terrain (i.e. they measure significant terrain points) the accuracy of resulting DTM is very high.{4}.

2.2.2 Aerial and Space images

Arial images are the most effective way to produce and update topographic maps. It has been estimated that all topographic maps have been produced by photogrammetric techniques using aerial photographs, Aerial photographs are also the most valuable data source for large- scale production of high- quality

DTMs. The accuracy of photogrammetric data depends on the images used. In the case of space photogrammetric using satellite images, the accuracy could be lower, depending on resolution. In the terms of efficiency, most of the processes in photogrammetric technique have been automated now a day and thus data acquisition is more efficient. {4}.

2.2.3 Topographic Maps.

Most of the DTMs currently available have been interpolated from counters by sampling designs and computer algorithms that add artifacts and other distortions inherent in the processing. This analog data may be digitized through manual digitization or by means of automatic raster scanning and vectorization. The accuracy of this method is relatively low. In the terms of efficiency the speed of operation for map digitization is very slow. Conversely the raster scanning process which can easily be automated but human interference is still needed during the raster and vector conversions. {4}

2.2.4 Airborne Laser Scanning (ALS)

During the past few years airborne laser scanning has become a reliable technique for data capture from the earth surface. Using a laser scanner for data acquisition will yield to a 3D point cloud that consists of quasi randomly distribution points. The exterior orientation can be accomplished by Global Position System (GPS) and Inertial Navigation System (INS). The reduction of costs for Digital Surface Model (DSM) production and increase of reliability, precision and completeness play a major role in preferring laser altimetry as the acquisition method above analytical or digital photogrammetry. The two major problems in this field are the detection and correction of systematic errors in the laser scanner data and separation of ground points from points resulting from reflections on buildings, vegetation or other object above the ground.

The elevation accuracy of Light Detection And Ranging (LIDAR) data is usually in the 15 to 25 cm range, making it suitable for some applications that require accurate 3D data in urban areas such as 3D city Modeling. Because LIDAR systems generate 3D coordinates of terrain points directly, the production cycle is shorter than photogrammetric methods. {4}.

2.2.5 Imaging RADAR Data

The last two decades have witnessed unprecedented growth in the satellite based Earth-observation-industry. Although the market is still strongly biased toward electro-optically derived imagery, a rising tide of acceptance and usage of satellite – derived synthetic aperture radar (SAR) data has occurred during the last few years. This trend is the result of the increasing availability of commercial SAR satellite data, development of sophisticated processing and analysis tools, and industry- driven training initiatives to familiarize image analysis with SAR imagery, including its interpretation and utility. {4}.

CHAPTER THREE

Interpolation Methods in Arc GIS

3.1 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.

3.2 Interpolation

Spatial interpolation is the procedure of estimatingthe value of properties at unsampled sites within thearea covered by existing observations in almost all cases the property must be interval or ratio ScaledCan be thought of as the reverse of the process usedto select the few points from a DTM whichaccurately represent the surfaceRationale behind spatial interpolation is theobservation that points close together in space aremore likely to have similar values than points far apart.{5}.

Spatial interpolation is a very important feature of .many GISs and may be used in GISs:

-To provide contours for displaying data graphically.

-To calculate some property of the surface at a given point.

-To change the unit of comparison when using differentdata structures
in different layers.

Point interpolation is used for data which can be collected atpoint locations (e.g. weather station readings, spot heights, oil wellreadings, porosity measurements). The available interpolation methods are:

3.2.1 Inverse Distance Weighted (IDW)

Inverse Distance Weighted (IDW) interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. The surface being interpolated should be that of a locationally dependent variable. {6}.

The Inverse Distance Weighting (IDW) algorithm effectively is a moving average interpolator that is usually applied to highly variable data. For certain data types it is possible to return to the collection site and record a new value that is statistically different from the original reading but within the general trend for the area. IDW interpolation explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. To predict a value for any unmeasured location, IDW will use the measured values surrounding the prediction location. Those measured values closest to the prediction location will have more influence on the predicted value than those farther away. Thus, IDW assumes that each measured point has a local influence that diminishes with distance. The IDW function should be used when the set of points is dense enough to capture the extent of local surface variation needed for analysis. IDW determines cell values using a linear-weighted combination set of sample points. It weights the points closer to the prediction location greater than those farther away, hence the name inverse distance weighted.The IDW technique calculates a value for each grid node by examining surrounding data points that lie within a user-defined search radius. Some or all of the data points can be used in the interpolation process.

The node value is calculated by averaging the weighted sum of all the points. Data points that lie progressively farther from the node influence the computed value far less than those lying closer to the node show in Figure 3.2.

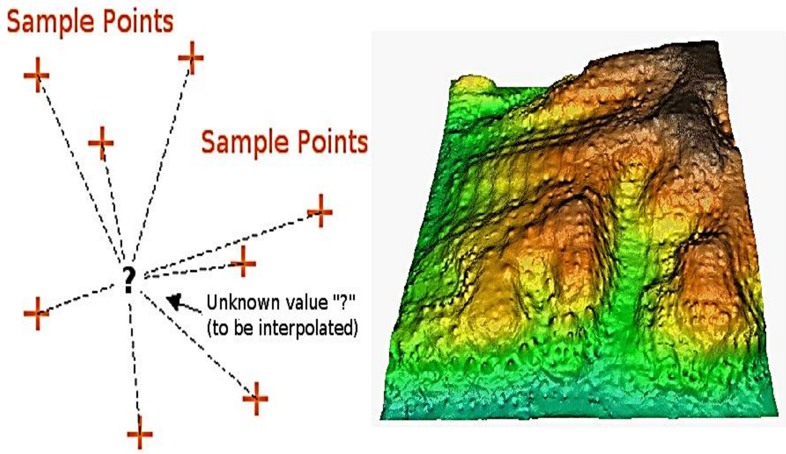

Figure **3.2** Calculating by average points.

Using the so-called "Inverse Distance Weighting" method or IDW, the weight of any known point is set inversely proportional to its distance from the estimated point. It is calculated as follows:

$$\mathbf{Z} = \sum_{i=1}^{n} \left(\frac{1}{di} Zi \right) / \sum_{i=1}^{n} \left(\frac{1}{di} \right) \ldots\ldots\ldots\ldots\ldots (3.1)$$

Where;

Z = value to be estimated.

Z i = Known value.

di = distances from the data points to the unknown point.

i = 1 to n.

n = the number of sample points.

The advantage of IDW can be summarized as:

1. Can estimate extreme changes in terrain such as: Cliffs, Fault Lines.
2. Dense evenly space points are well interpolated (flat areas with cliffs).
3. Can increase or decrease amount of sample points to influence cell values.

On the other used the disadvantages are:

1. Cannot estimate above maximum or below minimum values.
2. Not very good for peaks or mountainous areas.

3.2.2 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 kriging estimate is a weighted linear combination of the known sample values around the point to be estimated.

Kriging, procedure that generates an estimated surface from a scattered set of points with z-values. 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.

Krigingis 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. {7}.

The predicted values are derived from the measure of relationship in samples using sophisticated weighted average technique. It uses a search radius that can be fixed or variable. The generated cell values can exceed value range of samples, and the surface does not pass through samples. Kriging is similar to IDW in that it weights the surrounding measured values to derive a prediction for an unmeasured location. The general formula for both interpolators is formed as a weighted sum of the data:

$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i) \quad \text{………………} \ (3.2)$$

Where:

$Z(s_i)$ = the measured value at location.

λi = an unknown weight for the measured value at location.

S_0 = the prediction location.

N = the number of measured values.

The formula involves calculating the difference squared between the values of the paired locations.

The image below in Figure**3.3** shows the pairing of one point (the red point) with all other measured locations. This process continues for each measured point.

Often, each pair of locations has a unique distance, and there are often many pairs of points. To plot all pairs quickly becomes unmanageable. Instead of plotting each pair, the pairs are grouped into lag bins. For example, compute the average semi variance for all pairs of points that are greater than 40 meters apart but less than 50 meters. The empirical semivariogram is a graph of the averaged semivariogram values on the y-axis and the distance (or lag) on the x-axis (see diagram below) in Figure 3.4.

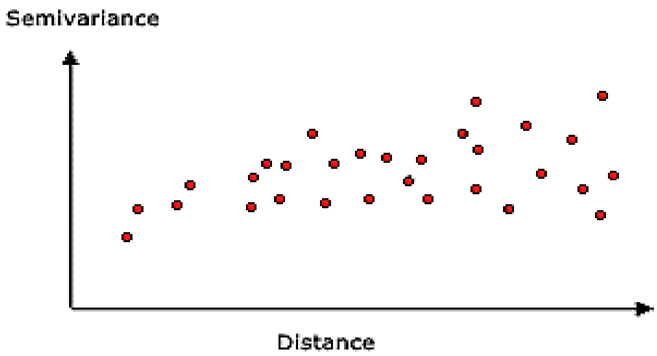

Figure **3.4**Empiricalsemivariogram graph example

In IDW, the weight, λi, depends solely on the distance to the prediction location. However, with the kriging method, the weights are based not only on the distance between the measured points and the prediction location but also on the overall spatial arrangement of the measured points. To use the spatial arrangement in the weights, the spatial autocorrelation must be quantified. Thus, in ordinary kriging, the weight, λi, depends on a fitted model to the measured points, the distance to the prediction location, and the spatial relationships among the measured values around the prediction location. The following sections discuss how the general kriging formula is used to create a map of the prediction surface and a map of the accuracy of the predictions.

The advantage of IDW can be summarized as:

1. Directional influences can be accounted for: Soil Erosion, Siltation Flow, Lava Flow and Winds.
2. Exceeds the minimum and maximum point values

On the other used the disadvantages are:

1. Does not pass through any of the point values and causes interpolated values to be higher or lower then real values.

3.2.3 Natural Neighbor

Natural Neighbor method was developed in 1980 by Sibson. This method is based on voronoi pattern for a set of separated points. Voronoi pattern is a diagram, which is dividing space into a number of regions. This method has more advantage compared with the nearest neighbor's method, such as ability to create a surface that is relatively smooth. This method is based on following function:

$$Z(x, y) = \sum_{i=1}^{n} \mathrm{wi} * Z(\mathrm{xi}, \mathrm{yi}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.3)$$

Where:

Z(x, y) = the estimated height at unknown point.

Z (xi,yi) = height of sample point.

i and wi = weight of sample i followed by the area enclosed by any parts of the unknown sample point.

The Natural Neighbor interpolation algorithm uses a weighted average of the neighboring observations, where the weights are proportional to the ‘borrowed’ area. The Natural Neighbor method does not extrapolate contours beyond the convex hull of the data locations. The gridding method uses a weighted average of the neighboring observations and generates good contours from data sets containing dense data in some areas and sparse data in other areas. The natural neighbors of any point are those associated with neighboring Voronoi (Thiessen) polygons. Initially, a Voronoi diagram is constructed of all the given points, represented by the olive-colored polygons. {8}.

3.3 Interpolating of Elevation Surface

A typical use for point interpolation is to create an elevation surface from a set of sample measurements.

In the Figer**3.6** and Figer**3.7**, each symbol in the point layer represents a location where the elevation has been measured. By interpolating, the values for each cell between these input points will be predicted.

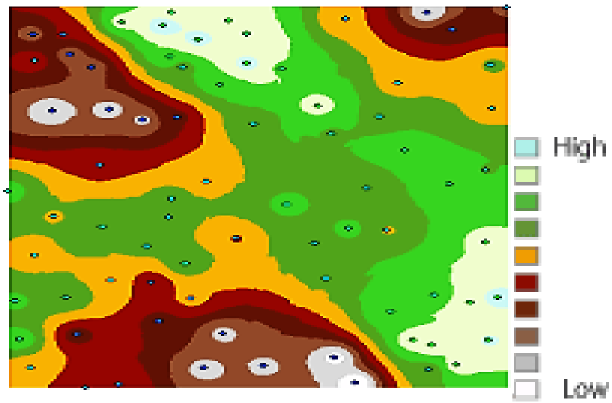

Figure **3.6** Interpolated elevation surface.

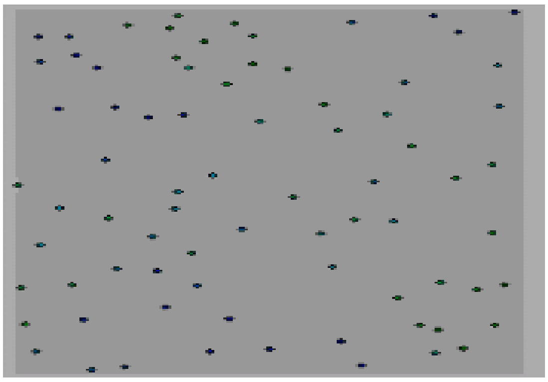

Figure **3.8**Input elevation point data.

CHAPTER FOUR

Methodology

4.1 Introduction

In this research we want to extract elevations using different interpolation methods in Geographic Information System (GIS) by test points, which have been selected from the all points, so we create a digital terrain model.

4.2 Study Area

Two sites have been selected as are study area in this study.

4.2.1 Study Area (A)

The first site is located in the west of Omdurman **(A)** between latitude **15 35 52**and longitude **32 16 57**,projected coordinates system, (**UTM**) ,(**WGS 84**) (**Zone 36**). It covers an area of 6.8 sq. km. an area with different topography, where the difference between the highest point and lowest point in the range of 14 meters.

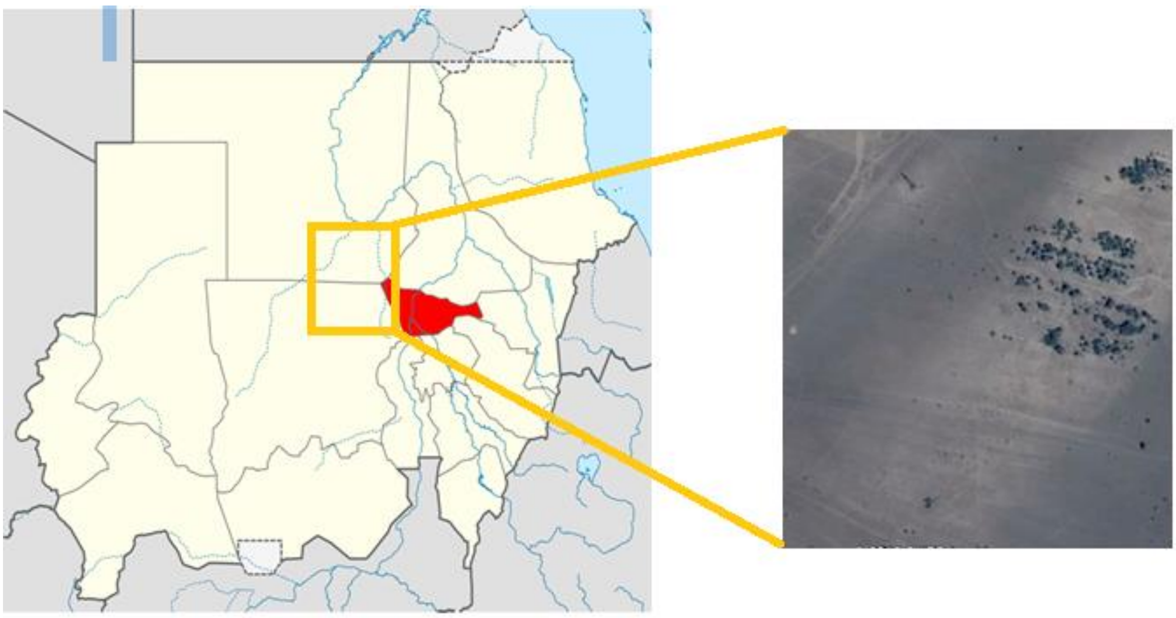

Figure **4.1** first study area **(A)**.

4.2.2 Study Area (B)

The second site is located in the north of Aldbassin Bridge(**B**) between latitude**15 33 38** and longitude**32 27 21**,projected coordinates system, (**UTM**) ,(**WGS 84**) (**Zone 36**). It covers an area of 0.16 sq. km, an area with different topography, where the difference between the highest point and lowest point in the range of 1.8 meters.

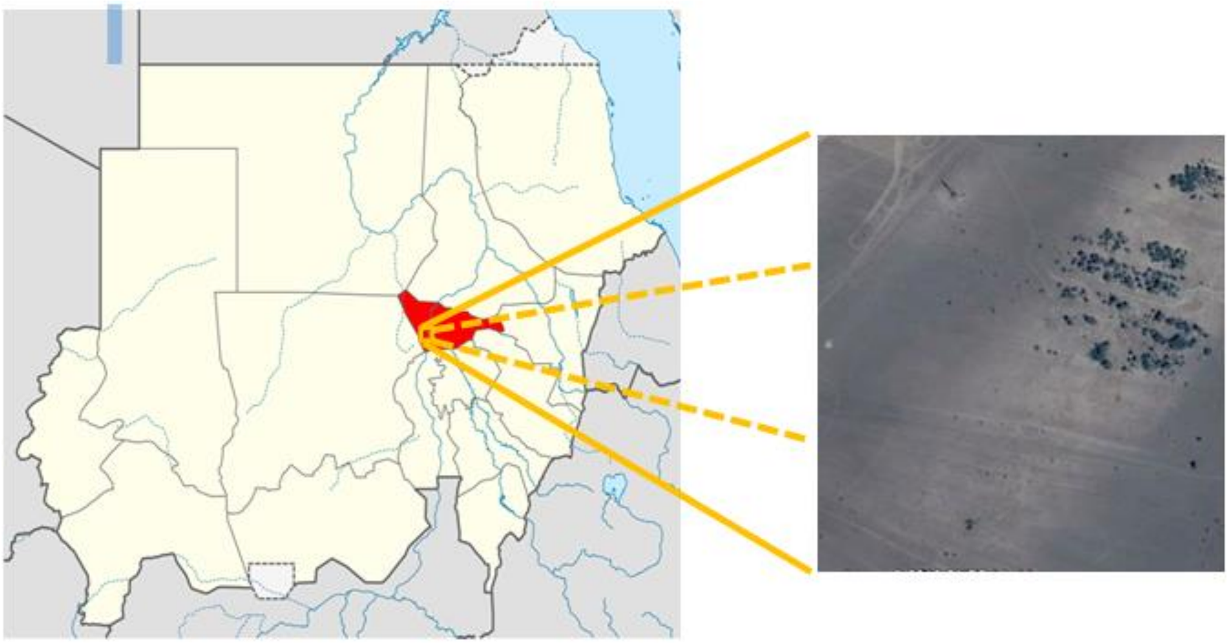

Figure (4.2) second study area **(B)**.

4.3 Arc GIS

Arc GIS is geographic information system (GIS) for working with maps and geographic information. It is used for creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information, using maps and geographic information in a range of applications, and managing geographic information in a database.

The system provides an infrastructure for making maps and geographic information available throughout an organization, across a community, and openly on the web.

4.4 Test Data

In the study area (A) a digital terrain model has been produced using total station, thearea (2.6km*2.6km). The subdivision of the internal lines is 100 meters, the total points are 196. In the second study area a digital terrain model has been produced using total station and digital level, the area (400m *400m).The subdivision of theinternallines is 50 meters, the total points are 81.

4.5Procedure

The research isconsistingof three phases (Figure 4.3). Phaseone concern with data acquisition. In phase two the Z- values for the reference points have been extracted from a DTM. Phase three is anassessment in which evaluated using different statistical methods.

Conceptual Frame Work

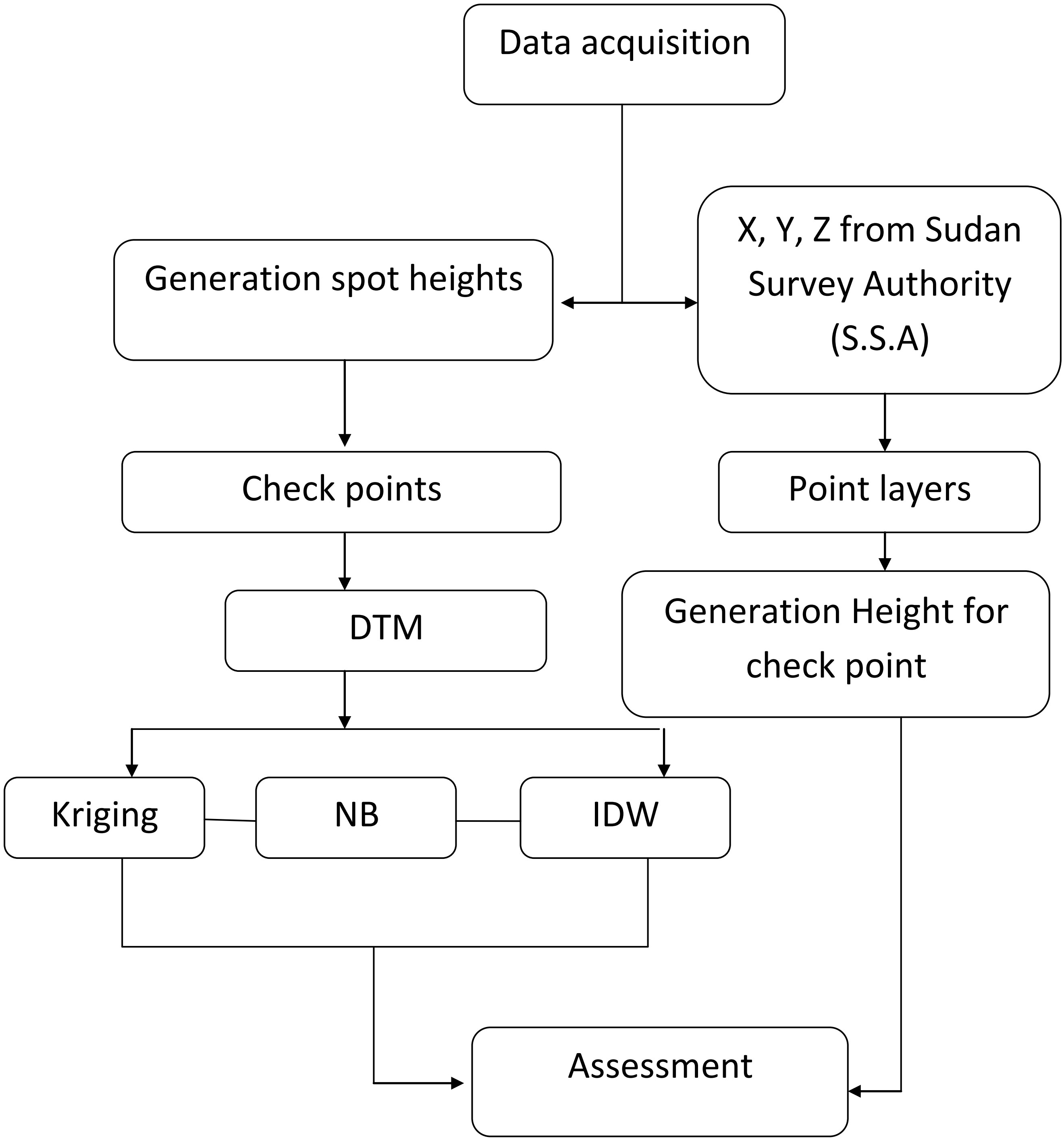

Figure 4.3 Frame of work.

4.5.1 Data Acquisition

The data utilized for the research were obtained from two areas, area (A) with different topography, and (B) is semi flat. These include orthometric heights obtained from total station using two reference points of the main sea level, the number of points about 196 points(bench marks).Inarea (B) total of 81points (bench marks) were observed using both total station and digital level using two reference points of the main sea level.

4.5.2 Generation of spot Heights values

Points made in GIS and adjusting the reference geographical zones to match them on the ground and created a digital terrain model (DTM) of two regions by three methods used in this research.

4.5.3Assessment

Certain statistical measures are built in the GIS software. These statistics are used during the analysis while interpolation techniques. Once all the interpolation techniques are chosen, additional statistics are used based on the model evaluation. The final choice of the better technique was based on the accuracy of the predictions. The differences between the known valueand the predictedwere calculated. The residuals were spatially interpolated usingKriging,NB and IDW.The following performance measures were applied:

4.5.3.1 Root Mean Square Error (RMSE)

The first test we used to investigate the spatial interpolation and regression techniques is the Root Mean Square Error (RMSE). RMSE is commonly used to measure the success of numeric prediction. It is a measure of the average error a cross a map and is used in coordinates and the registration points. RMSE is the square rootof the square of the difference between estimated point and interpolated observation point divided by the total number of the observation points:{9}.

$$\text{RMSE} = \sqrt{\sum_{i=1}^{n} (Zcomp - Zactual)^{2} / (n)} \quad \text{.............. (4.1)}$$

n : total number of points in array E and N.

4.5.3.2 Standard Deviation

The standard deviation is a numerical value used to indicate how widely individuals in a group vary. If individual observations vary greatly from the group mean, the standard deviation is big and vice versa. It is important to distinguish between the standard deviation of population and standard deviation of sample. They have different notation, and are computed differently. {10}.

The standard deviation of sample is defined by slightly different formula:

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2} \quad \text{.......................... (4.2)}$$

Where

S =the standard deviation.

xi = the elements of the sample .

$\overline{x}$ =the sample mean.

N =the number of elements in the sample.

And finally, the standard deviation is equal to square root of the variance.

CHAPTER FIVE

Results

5.1 Results of the Study Area (A)

After entering the test points of area A in the GIS program and make the necessary analysis the surfaces and results were as follow:

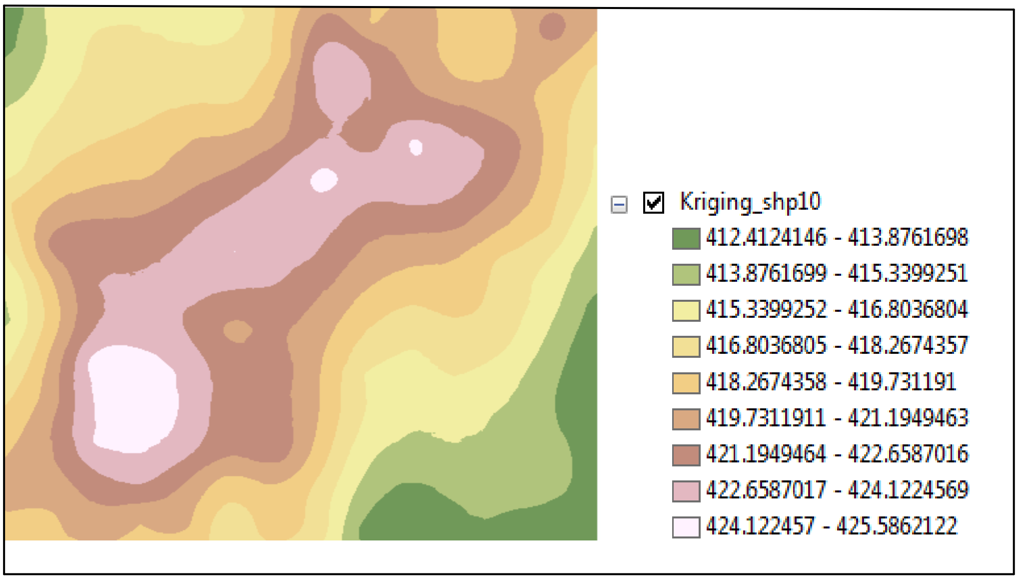

Figure**5.1**Kriging Surfacearea (**A**)

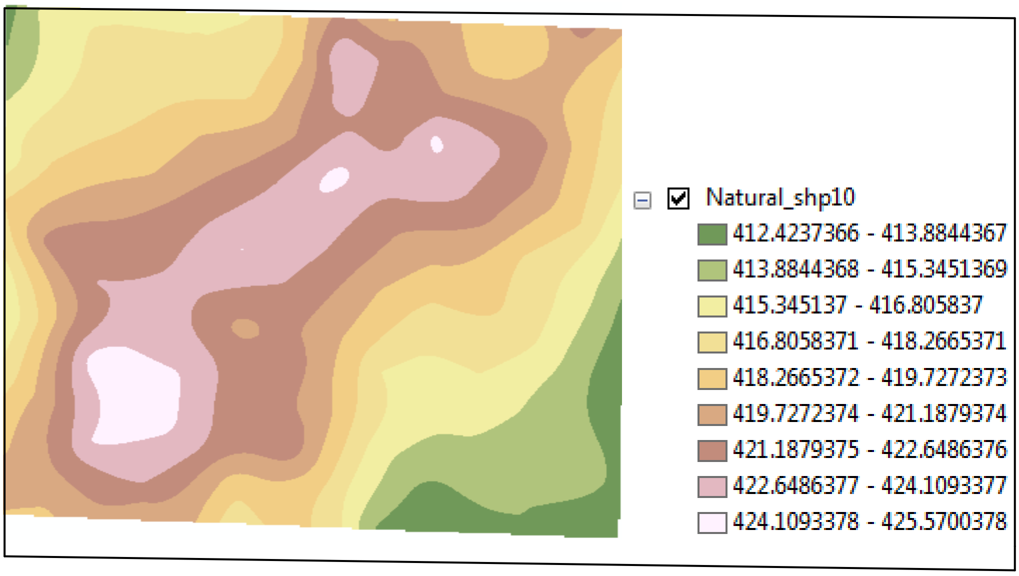

Figure**5.2** NB Surface area (**A**)

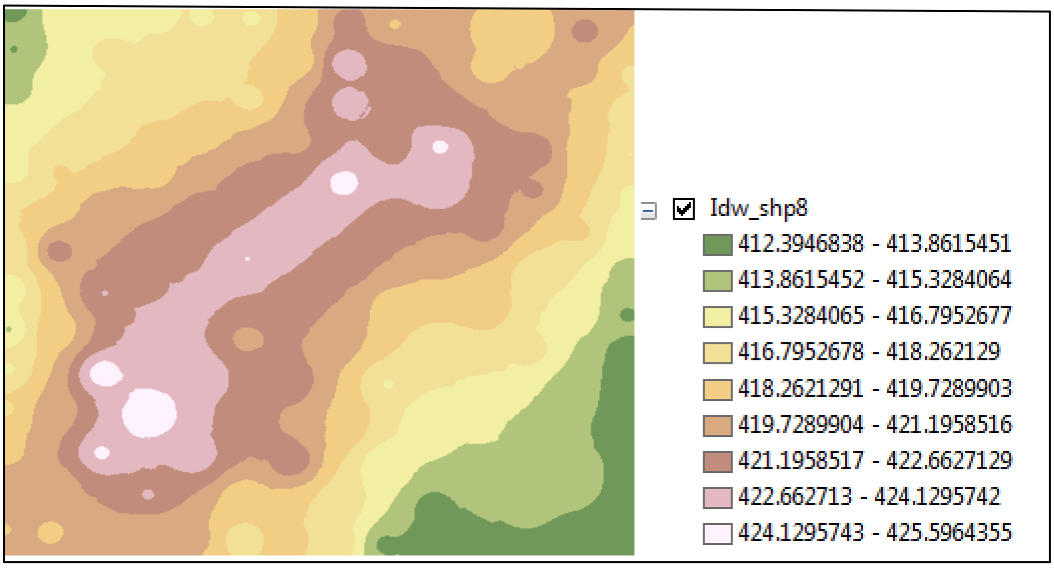

Figure**5.3** IDW Surfacearea(**A)**

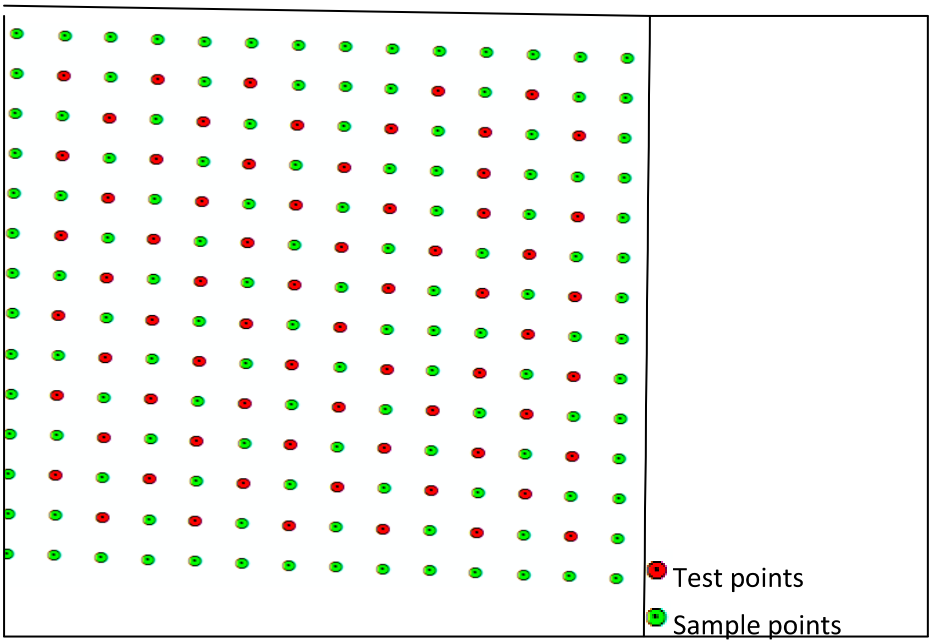

Figure**5.4**The Elevation of study area **(A**)

After entering the test points to the program and extraction the new heights values by three interpolation methods in area (A) the results were as shown in the table 4.1.

Table (4.1) show the results of Almuilih after deleting first time

Point		Reference Coordinates			Height (m)			Residuals					
Serial No	ID	E (m)	N (m)	H (m)	Kriging	NB	IDW	Kriging	NB	IDW	Kriging^2/n	NB^2/n	IDW^2/n
0	A16	423109.154	1724593.519	413.920	414.013	413.944	413.827	-0.093	-0.024	0.093	0.0001	0.0000	0.0001
1	A18	422711.295	1724612.480	414.370	413.985	414.051	414.015	0.385	0.319	0.355	0.0022	0.0015	0.0019
2	A19	422515.353	1724823.797	414.450	414.870	414.988	415.145	-0.420	-0.538	-0.695	0.0026	0.0043	0.0071
3	A22	422311.219	1724631.547	414.620	414.875	415.108	415.581	-0.255	-0.488	-0.961	0.0010	0.0035	0.0136
4	A24	423114.996	1724995.066	414.900	414.370	414.395	414.272	0.530	0.505	0.628	0.0041	0.0038	0.0058
5	A28	423122.912	1725394.142	415.270	415.219	415.247	415.062	0.051	0.023	0.208	0.0000	0.0000	0.0006
6	A33	422717.131	1725013.907	415.710	415.684	415.663	415.618	0.026	0.047	0.092	0.0000	0.0000	0.0001
7	A34	422918.916	1725204.137	415.760	415.981	415.921	415.689	-0.221	-0.161	0.071	0.0007	0.0004	0.0001
8	A36	422317.056	1725032.974	416.010	416.800	416.957	417.288	-0.790	-0.947	-1.278	0.0092	0.0132	0.0240
9	A40	420950.493	1726900.395	416.270	415.904	415.948	415.840	0.366	0.322	0.430	0.0020	0.0015	0.0027
10	A43	422521.057	1725223.098	416.540	416.352	416.514	416.917	0.188	0.026	-0.377	0.0005	0.0000	0.0021
11	A54	422913.211	1724804.836	416.940	415.046	414.937	414.624	1.894	2.003	2.316	0.0527	0.0590	0.0789
12	A56	423128.754	1725795.699	417.020	416.707	416.792	416.706	0.313	0.228	0.314	0.0014	0.0008	0.0015
13	A57	421350.569	1726881.328	417.110	417.021	417.044	417.055	0.089	0.066	0.055	0.0001	0.0001	0.0000
14	A59	421748.437	1726862.367	417.130	417.214	417.535	418.171	-0.084	-0.405	-1.041	0.0001	0.0024	0.0159
15	A60	422926.970	1725605.459	417.150	417.677	417.593	417.442	-0.527	-0.443	-0.292	0.0041	0.0029	0.0013
16	A66	421148.683	1726688.971	417.520	417.316	417.271	417.123	0.204	0.249	0.397	0.0006	0.0009	0.0023
17	A69	421546.658	1726672.257	417.770	417.874	417.955	417.989	-0.104	-0.185	-0.219	0.0002	0.0005	0.0007
18	A70	420944.681	1726498.837	417.850	417.149	417.219	417.030	0.701	0.631	0.820	0.0072	0.0059	0.0099
19	A75	421344.726	1726479.771	418.040	418.554	418.594	418.666	-0.514	-0.554	-0.626	0.0039	0.0045	0.0058
20	A77	422325.008	1725432.168	418.190	418.129	418.337	418.681	0.061	-0.147	-0.491	0.0001	0.0003	0.0035
21	A79	422722.866	1725413.207	418.270	417.585	417.519	417.441	0.685	0.751	0.829	0.0069	0.0083	0.0101
22	A86	422115.277	1724842.864	418.980	419.106	418.934	418.521	-0.126	0.046	0.459	0.0002	0.0000	0.0031
23	A87	421140.740	1726289.766	418.990	419.076	419.066	418.948	-0.086	-0.076	0.042	0.0001	0.0001	0.0000
24	A88	420925.197	1725298.904	419.000	420.322	420.356	420.046	-1.322	-1.356	-1.046	0.0257	0.0270	0.0161
25	A95	420930.902	1725698.215	419.190	419.771	419.819	419.454	-0.581	-0.629	-0.264	0.0050	0.0058	0.0010
Follow													

26	A99	422120.976	1725242.045	419.410	419.712	419.669	419.595	-0.302	-0.259	-0.185	0.0013	0.0010	0.0005
27	A101	422932.705	1726004.769	419.440	419.935	419.836	419.522	-0.495	-0.396	-0.082	0.0036	0.0023	0.0001
28	A103	423142.503	1726596.322	419.490	419.241	419.238	419.335	0.249	0.252	0.155	0.0009	0.0009	0.0004
29	A104	421742.601	1726460.939	419.520	419.829	419.949	420.188	-0.309	-0.429	-0.668	0.0014	0.0027	0.0066
30	A105	422742.451	1726615.268	419.520	421.112	421.073	421.018	-1.592	-1.553	-1.498	0.0373	0.0355	0.0330
31	A112	422739.470	1726413.431	419.790	423.041	422.862	422.118	-3.251	-3.072	-2.328	0.1555	0.1388	0.0797
32	A113	421717.412	1724861.695	419.810	421.627	421.568	421.371	-1.817	-1.758	-1.561	0.0486	0.0455	0.0359
33	A116	422946.453	1726805.392	420.040	419.655	419.629	419.829	0.385	0.411	0.211	0.0022	0.0025	0.0007
34	A117	421944.410	1726651.048	420.060	420.241	420.186	420.731	-0.181	-0.126	-0.671	0.0005	0.0002	0.0066
35	A121	421723.107	1725261.007	420.210	421.976	422.039	422.169	-1.766	-1.829	-1.959	0.0459	0.0492	0.0565
36	A125	420919.468	1724899.724	420.540	421.260	421.188	420.927	-0.720	-0.648	-0.387	0.0076	0.0062	0.0022
37	A127	422730.880	1725814.531	420.560	419.639	419.624	419.439	0.921	0.936	1.121	0.0125	0.0129	0.0185
38	A128	422546.377	1726824.459	420.580	420.688	420.882	420.950	-0.108	-0.302	-0.370	0.0002	0.0013	0.0020
39	A130	421336.820	1726080.695	420.670	421.010	421.024	421.055	-0.340	-0.354	-0.385	0.0017	0.0018	0.0022
40	A131	422330.804	1725833.597	420.720	420.799	420.915	420.952	-0.079	-0.195	-0.232	0.0001	0.0006	0.0008
41	A134	421540.816	1726270.700	420.850	420.561	420.574	420.594	0.289	0.276	0.256	0.0012	0.0011	0.0010
42	A136	423136.691	1726194.773	421.000	419.082	418.946	418.671	1.918	2.054	2.329	0.0541	0.0620	0.0797
43	A137	422129.025	1725643.487	421.230	421.155	421.111	420.899	0.075	0.119	0.331	0.0001	0.0002	0.0016
44	A138	422344.593	1726634.229	421.240	422.538	422.265	422.280	-1.298	-1.025	-1.040	0.0248	0.0155	0.0159
45	A139	421924.916	1725451.116	421.280	421.348	421.347	421.350	-0.068	-0.067	-0.070	0.0001	0.0001	0.0001
46	A140	421135.035	1725890.465	421.300	422.142	421.844	421.071	-0.842	-0.544	0.229	0.0104	0.0043	0.0008
47	A143	422534.836	1726023.730	421.550	421.923	421.831	421.597	-0.373	-0.281	-0.047	0.0020	0.0012	0.0000
48	A147	422736.615	1726213.840	421.650	422.968	422.589	421.952	-1.318	-0.939	-0.302	0.0256	0.0130	0.0013
49	A154	421913.355	1724650.378	421.980	419.522	419.446	419.035	2.458	2.534	2.945	0.0889	0.0944	0.1275
50	A155	421728.842	1725660.307	422.030	422.610	422.582	422.544	-0.580	-0.552	-0.514	0.0049	0.0045	0.0039
51	A158	421532.900	1725871.624	422.160	422.990	422.834	422.536	-0.830	-0.674	-0.376	0.0101	0.0067	0.0021
52	A159	421126.982	1725489.144	422.360	422.701	422.494	421.820	-0.341	-0.134	0.540	0.0017	0.0003	0.0043
53	A162	421938.675	1726251.738	422.370	422.911	422.740	422.425	-0.541	-0.370	-0.055	0.0043	0.0020	0.0000
54	A168	421513.309	1724669.444	422.790	421.113	421.253	421.004	1.677	1.537	1.786	0.0414	0.0347	0.0469
55	A169	421919.197	1725051.935	422.790	421.713	421.451	420.936	1.077	1.339	1.854	0.0171	0.0264	0.0505
Follow													

56	A172	421527.058	1725470.077	423.090	422.574	422.643	422.817	0.516	0.447	0.273	0.0039	0.0029	0.0011
57	A173	421330.978	1725679.148	423.120	422.836	422.748	422.585	0.284	0.372	0.535	0.0012	0.0020	0.0042
58	A175	422338.757	1726232.801	423.210	423.311	423.074	422.927	-0.101	0.136	0.283	0.0002	0.0003	0.0012
59	A176	420938.961	1726099.656	423.420	419.928	419.787	419.128	3.492	3.633	4.292	0.1793	0.1942	0.2709
60	A177	421317.326	1724880.763	423.440	424.406	424.047	423.272	-0.966	-0.607	0.168	0.0137	0.0054	0.0004
61	A180	421323.061	1725280.072	423.730	424.726	424.378	423.684	-0.996	-0.648	0.046	0.0146	0.0062	0.0000
62	A181	422134.754	1726042.667	423.820	423.423	423.206	422.806	0.397	0.614	1.014	0.0023	0.0056	0.0151
63	A184	421736.896	1726061.628	423.980	423.027	422.870	422.576	0.953	1.110	1.404	0.0134	0.0181	0.0290
64	A185	421932.946	1725852.559	424.050	423.457	423.225	422.782	0.593	0.825	1.268	0.0052	0.0100	0.0236
65	A192	421519.111	1725071.003	425.500	423.795	423.621	423.274	1.705	1.879	2.226	0.0428	0.0519	0.0729
66	A193	422142.677	1726441.873	425.570	422.656	422.674	422.637	2.914	2.896	2.933	0.1248	0.1234	0.1265
67	A195	421115.440	1724688.405	426.850	422.148	422.084	421.559	4.702	4.766	5.291	0.3252	0.3340	0.4117
68	A196	421121.247	1725089.834	428.290	424.298	423.895	422.899	3.993	4.395	5.391	0.2344	0.2840	0.4274
Sum								9.755	13.036	23.968	1.6976	1.7522	2.1736
Average								0.279	0.372	0.685			
Standard Deviation							±	1.295	1.31	1.432			
RMSE								1.303	1.324	1.474	1.3029	1.324	1.4743

4.7 Resultsofthe Second Study Area (B):

After entering the test points of area B in the GIS program and make the necessary analysis the surfaces and results were as follow:

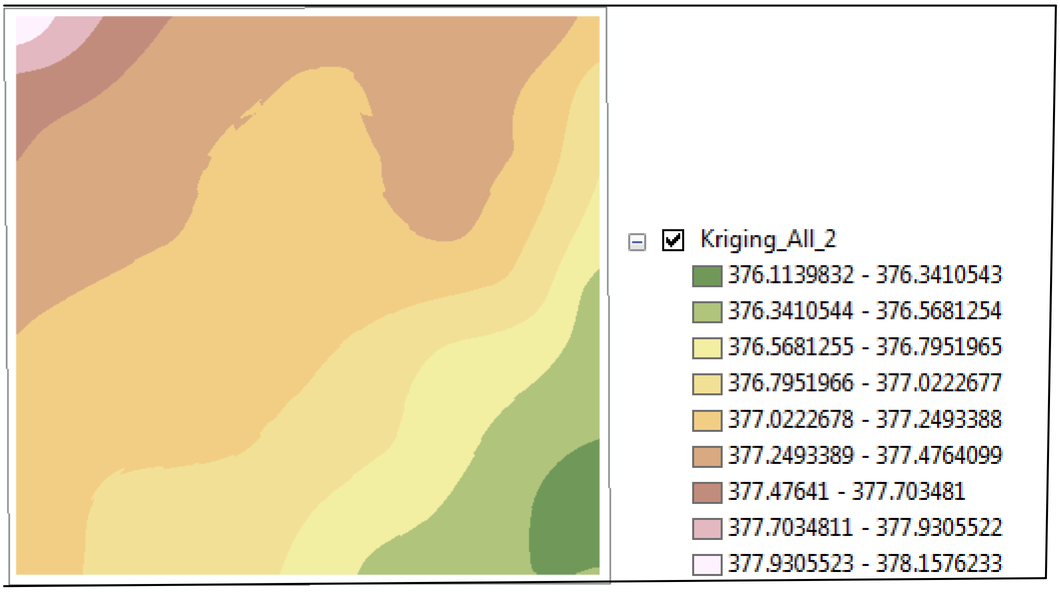

Figure**5.5**Kriging Surface study area (B)

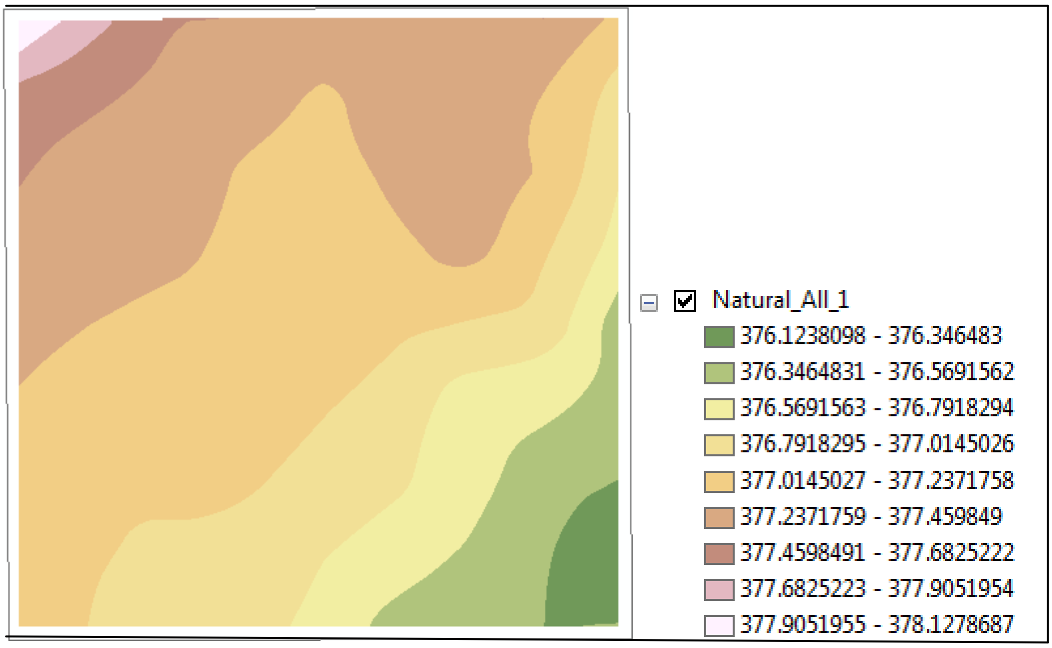

Figure**5.6**NB Surface study area (B)

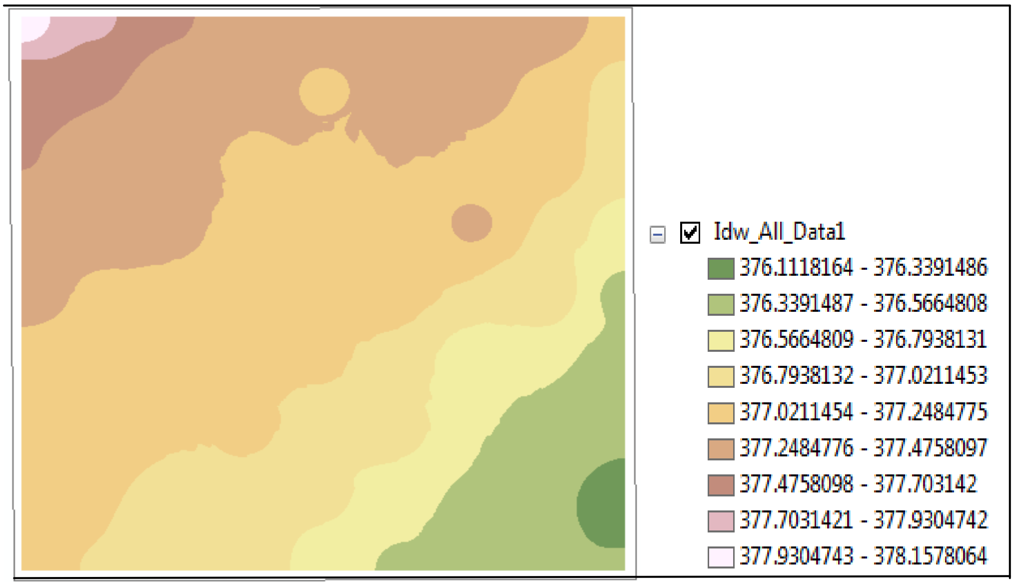

Figure**5.7**IDW Surface area (B)

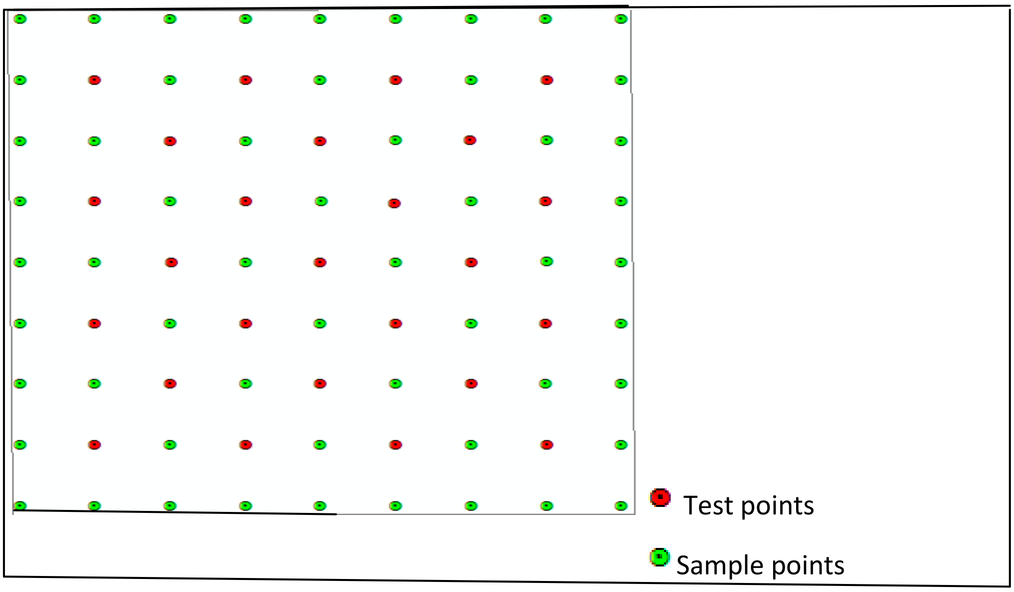

Figure**5.8**The Elevation of study area (B)

After entering the test points to the program and extraction the new heights values by three interpolation methods in area B the results were as shown in the table 4.2

Table (4.2) shows the results of Study area (B).

Point		Reference Coordinates			Height (m)			Residuals					
Serial No	ID	E (m)	N (m)	H (m)	Kriging	NB	IDW	Kriging	NB	IDW	Kriging^2/n	NB^2/n	IDW^2/n
1	1	441656.814	1720429.121	377.354	377.291	377.300	377.330	0.062	0.054	0.024	0.0002	0.0001	0.0000
2	5	441606.745	1720379.184	377.345	377.309	377.310	377.316	0.035	0.034	0.028	0.0001	0.0000	0.0000
3	7	441706.740	1720379.156	377.225	377.211	377.210	377.209	0.014	0.014	0.015	0.0000	0.0000	0.0000
4	9	441806.114	1720377.527	377.381	377.218	377.203	377.174	0.163	0.177	0.207	0.0011	0.0013	0.0017
5	11	441906.698	1720379.137	377.001	377.059	377.043	376.957	-0.059	-0.043	0.044	0.0001	0.0001	0.0001
6	15	441856.765	1720329.133	377.031	377.023	377.002	376.944	0.008	0.029	0.087	0.0000	0.0000	0.0003
7	17	441756.775	1720329.090	377.097	377.121	377.118	377.112	-0.025	-0.021	-0.015	0.0000	0.0000	0.0000
8	19	441657.166	1720329.043	377.151	377.197	377.195	377.193	-0.046	-0.044	-0.042	0.0001	0.0001	0.0001
9	23	441606.786	1720279.041	377.181	377.155	377.158	377.167	0.025	0.023	0.014	0.0000	0.0000	0.0000
10	25	441706.714	1720279.069	377.023	377.099	377.095	377.085	-0.077	-0.072	-0.062	0.0002	0.0002	0.0002
11	27	441806.781	1720279.130	376.957	376.912	376.915	376.921	0.045	0.041	0.035	0.0001	0.0001	0.0000
12	29	441906.679	1720279.154	376.576	376.629	376.637	376.624	-0.053	-0.061	-0.048	0.0001	0.0001	0.0001
13	33	441856.713	1720229.150	376.618	376.637	376.641	376.629	-0.019	-0.023	-0.011	0.0000	0.0000	0.0000
14	35	441756.715	1720229.074	376.892	376.954	376.944	376.911	-0.063	-0.052	-0.019	0.0002	0.0001	0.0000
15	37	441656.703	1720229.161	377.044	377.054	377.053	377.053	-0.010	-0.010	-0.010	0.0000	0.0000	0.0000
16	42	441606.835	1720179.130	377.044	377.024	377.029	377.045	0.020	0.015	-0.002	0.0000	0.0000	0.0000
17	44	441706.773	1720179.132	376.939	376.949	376.944	376.918	-0.010	-0.006	0.021	0.0000	0.0000	0.0000
18	46	441806.839	1720179.176	376.646	376.675	376.678	376.679	-0.030	-0.032	-0.033	0.0000	0.0000	0.0000
19	48	441906.718	1720179.201	376.474	376.363	376.373	376.417	0.110	0.101	0.056	0.0005	0.0004	0.0001
20	65	441606.729	1720479.148	377.503	377.520	377.515	377.531	-0.017	-0.012	-0.028	0.0000	0.0000	0.0000
21	67	441706.807	1720479.055	377.318	377.282	377.294	377.322	0.036	0.024	-0.005	0.0001	0.0000	0.0000
22	69	441806.729	1720479.163	377.240	377.259	377.268	377.278	-0.020	-0.029	-0.038	0.0000	0.0000	0.0001
23	71	441906.713	1720479.096	377.230	377.242	377.230	377.180	-0.012	0.000	0.050	0.0000	0.0000	0.0001
Follow													

24	75	441856.360	1720429.303	377.297	377.305	377.278	377.225	-0.008	0.019	0.072	0.0000	0.0000	0.0002
25	77	441756.767	1720429.095	377.215	377.212	377.220	377.238	0.002	-0.006	-0.023	0.0000	0.0000	0.0000
Sum								0.074	0.121	0.317	0.0028	0.0027	0.0032
Average								0.006	0.009	0.024			
Standard Deviation							**±**	0.054	0.0532	0.0561			
RMSE								0.053	0.052	0.056	0.05274	0.0524	0.05637

In the study Area (**A**) Table (4.3) the results of (SD) and (RMSE) are obtain as shown in the following table:

Table (4.3)

	Kriging	NB	IDW
SD	1.295	1.310	1.432
RMSE	1.303	1.324	1.474

In the study Area (**B**) Table (4.4) the results of (SD) and (RMSE) in first time are obtain as shown in the following table:

Table (4.4)

	Kriging	NB	IDW
SD	0.054	0.053	0.056
RMSE	0.053	0.052	0.056

CHAPTER SIX

Conclusions and Recommendations

6.1 Conclusions

Referring to the test carried out in this study it can concluded that:

1. The KrigingMethod is the best in this study.
2. With the availability of modern instruments with precision high, integration with smart software can save energy and money.
3. Reducing the number of points from the field in a systematic manner that will claim to be desired in terms of accuracy purpose.
4. Indifferent terrain must increase the number of readings of elevations until we get to better results.

6.2 Recommendations

Recommendations are summarized in the following:

1. The study area increased space in other areas such as agriculture, mining, to have the results.
2. The government interest in setting reference points and distribute them to states to facilitate cadastral business.
3. Surveyor engineers must interest in programs of engineering and business development engineering them.
4. Continue the research in the next period to resolve the problem of the elevations by smart software, and to reach satisfactory results in this regard.

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