Evaluating The Accuracy Of Digital Terrain Model

In Palestine (West Bank)

By:

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الإهــــــــــــــــداء

بدأنا بأكثر من يد وقاسينا أكثر من هم وعانينا الكثير من الصعوبات واليوم والحمد لله نطوي سهر الليالي وتعب الأيام وخلاصة مشوارنا بين دفتي هذا العمل المتواضع ، نسأل الله تعالى أن يتقبل منّا عملنا ويحفظه في ميزان حسناتنا .

نهدي هذا العمل المتواضع إلى

منارة العلم والإمام المصطفى إلى الأمي الذي علم المتعلمين إلى سيد الخلق إلى رسولنا الكريم سيدنا محمد صلى الله عليه وسلم .

أمـــــي ، أبي ..

إلى كل من ساهم في إنجاز هذا المشروع ..جامعة بوليتكنك فلسطين
دائرة الهندسة المدنية والمعمارية
إلى الشموع التي تحترق كي تضيء لنا الدرب ،أساتذتنا الأفاضل
إلى الدكتور غادي زكارنه
المهندس احمد الحرباوي
المهندس معتز قفيشه

إلى من هم أكرم منا جميعا .. الشهداء الذين ضحوا بحياتهم من أجل هذا الوطن
إلى الأحرار خلف القضبان .. الأسرى البواسل الذين ضحوا بحريتهم من أجل الوطن
إلى رفاق الدرب والأصدقاء .. الذين تابعو هذا المشروع خطوة بخطوة.

إلى من حبهم يجري في عروقي ويلج بذكراهم فؤادي، إلى أخواتي وأخواني
إلى الأعزاء ومن اشتاقت لهم قلوبنا وذرفت من أجلهم دموعنا وفرقتنا الاقدار

فريق العمل

الشكر والتقدير

إن الشكر والمنة لا تليق إلا لواهب العقول و منير الدروب لله عز وجل .

كما ونتقدم بجزيل الشكر والامتنان

إلى بانية الجيل الواعد ...جامعة بوليتكنك فلسطين .

إلى كلية الهندسة.

إلى دائرة الهندسة المدنية والمعمارية ....بطاقمها التدريسي و الإداري.

إلى الذين مهدوا لنا طريق الهداية والعلم والمعرفة ...

إلى جميع أساتذتنا الأفاضل ...

"كن عالما.. فإن لم تستطع فكن متعلما، فإن لم تستطع فأحب العلماء، فإن لم تستطع فلا تبغضهم"

إلى المشرف على هذا المشروع الدكتور ... غادي زكارنه .

والشكر الكبير لكل من ساهم في انجاز هذا البحث المتواضع .

فريق العمل

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Abstract

Digital elevation model (DEM) is a 3D digital representation for heights above the earth surface. If the surface is representing the terrain, then it called digital terrain model (DTM). Local DTM are often created by surveying or photogrammetry methods. While global DTM are mostly created by means of satellite images, Altimetry or LidAR. These models are commonly used by people, engineers and students. The accuracy of these DTM models are rarely discussed. Different models have different spatial resolution or contour intervals. But their accuracy are not truly introduced.

Our objective in this project is to evaluate the existing accuracy of the global or photogrammetric DTMs that are being commonly used in Palestine. This can be achieved by measuring the heights of a group of reference points all over Palestine (West Bank) and comparing their measured heights with the heights obtained from the DTM.

Evaluating The Accuracy Of Digital Terrain Model In Palestine (West Bank)

فريق العمل : محمود جمعة قرنه محمد وجيه الفطافطه

المشرف : د. غادي زكارنة

ملخص:

نموذج الارتفاعات الرقمي (Digital Elevation Modle) ، هو عبارة عن نموذج رقمي يمثل الارتفاعات المختلفة فوق سطح الارض ، أما اذا كان هذا النموذج يمثل تضاريس فقط يدعى بنموذج التضاريس الرقمي (Digital Terrain Model) ، وعادة ما يتم انشاء هذه النماذج الرقمية المحليه من خلال المساحة الارضية او من خلال التصوير الجوي ، أما النماذج العالمية فيتم انشاؤها من خلال صور وبيانات مأخوذة من الاقمار الصناعية ،وهذه النماذج يتم أستخدمها كمراجع من قبل المهندسين او الطلبة .

من النادر مناقشة دقة هذه النماذج ،لذلك فان مشروعنا يهدف الى فحص دقة هذه النماذج الرقمية للارتفاعات المستخدمة في فلسطين ،سواء العالمية او المحلية ، وتم تحقيق ذلك من خلال قياس ارتفاعات لعدد من النقاط المرجعيه في فلسطين ومقارنتها مع تلك التى يتم الحصول عليها من خلال النماذج الرقمية لارتفاعات التضاريس (DTM).

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1.1 Background

Digital elevation model (DEM) is a 3D digital representation for heights above the earth surface. If the surface is representing the terrain, then it called digital terrain model (DTM). Local DTM are often created by surveying or photogrammetry methods. While global DTM are mostly created by means of satellite images, Altimetry or LidAR. These models are commonly used by people, engineers and students. The accuracy of these DTM models are rarely discussed. Different models have different spatial resolution or contour intervals. But their accuracy are not truly introduced.

1.2 Objective

Our objective in this project is to evaluate the existing accuracy of the global or local photogrammetric DTMs that are being commonly used in Palestine. This can be achieved by measuring the heights of a group of reference points all over Palestine (West Bank) and comparing their measured heights with the heights obtained from the DTM.

1.3 Time Table:

The time schedule in table (1-1) shows the stages of developing theoretical work and the process project that includes (literature review, organizing the scope, data collection, and the final presentation).

Table (1-1) Time Schedule for this semester.

Weeks / Tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**16**
Project idea																
literature review																
organizing the scope																
Data collection																
Presentation																

1.4 Methodology

The Methodology of work in this project will be achieved by observing several points using the GNSS, covering the area of the west bank. Interpolation methods (nearest neighbored, Bi-linear, Bi-cubic) to extract the elevations of points, then using RMSE to find the difference between models values and observed values, to evaluate the accuracy of these models, as a final results.

1.5 Study Area

Study area of this project lies in Palestine (West Bank), between (34^o ,36^o) east and (29^o ,33^o) north, with referenced to WGS84 coordinates system.

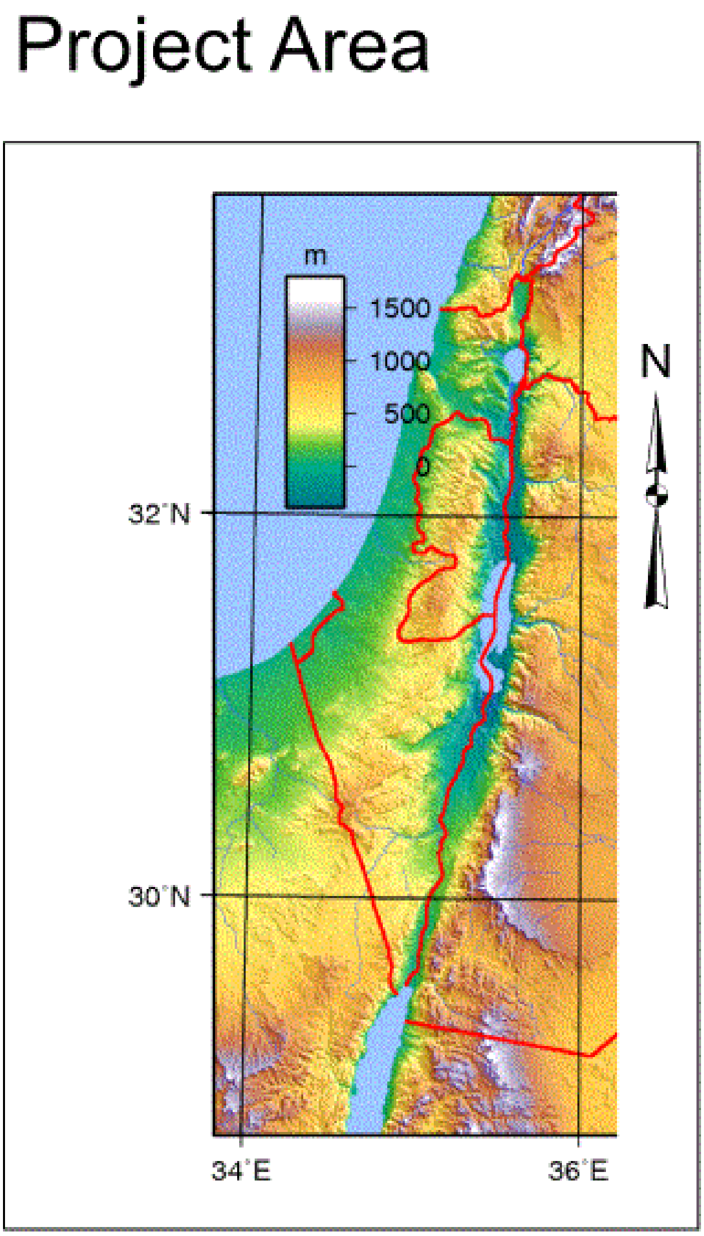

Figure (1-1) Study area

1.6 Project Scope

This project consists of seven chapters as follows:

- Chapter One: A simple explanation about the project and an introduction to what will be done in the project.
- Chapter Two: Principles of geographic information system.
- Chapter Three: Digital Elevation Model (DEM).
- Chapter Four: Work and Analysis .

Geographic Information System (GIS)

2.1 Introduction

2.2 Components of GIS

2.3 Sub-systems inside GIS

2.4 Types of data in GIS

2.5 Working of GIS

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2.7 Important sources of data for GIS

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2.1 Introduction

The rapid development in computer and information technology has helped in the best utilisation of remotely sensed data. Geographic information system has become a necessary tool in analysing and utilising remotely sensed satellite or photogrammetric data [1].

GIS is a computer system was designed to be able to make assembling, storing, manipulating, and displaying geographically referenced information, i.e. data identified according to their locations. GIS as a computer-based tool is used for mapping and analysing events that happen on earth by integrating common database operations such as query and statistical analysis with visualisation and geographic analysis of maps. In a simple way GIS is a link between maps and databases .

GIS is also referred as a "system of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modular and display of spatially referenced data for solving complex planning and management problems"[1].

Mapmaking and geographic analysis are not new, but a GIS performs these tasks better and faster than the old manual methods. Siting of water harvesting structures, finding the best soil for growing paddy, or figuring out the best route for an emergency vehicle, or local problems, all with geographical components can be handled effectively using GIS. GIS can create maps, integrate information, visualise scenarios, solve complicated problems, present powerful ideas, and develop effective solutions.

2.2 Components of GIS

GIS consists of five key components, which are: Hardware, Software, Data, People and Methods.

2.2.1 Hardware

GIS hardware includes: computers, computer configuration/networks, input devices, printers, and storage systems.

Computers for GIS usage can be PCs at the low end, or supercomputers and X-Terminals at the high end. These computers can be stand-alone units or can be hooked into a network environment. To assist with source data capture & real -time GIS data, many companies are employing handheld technologies in the form of PDA's and GPS units. The latter also affords companies the ability to track moving features, adding a new dimension to their GIS solutions.

Input devices include digitizers and scanners. A digitizer is the device used for selecting features from a hard copy map, which are then registered to a coordinate system. Currently digitizing is the most common method for converting existing maps and images into digital form. However, this process can be tedious, especially when converting high-density maps. Scanners sometimes can replace digitizing by automatically converting hard-copy maps to a digital raster file. Once in a GIS, the raster image can be converted to a vector format through a “raster-to-vector” conversion [3].

The third hardware component is the printer/plotter. These devices are used to produce a hardcopy map. There are several types of printers including: matrix, inkjet/bubblejet and laser. Plotter types include: laser, electrostatic, direct thermal and pen plotter.

Finally, GIS storage systems include: optical disks, magnetic disks (such as a hard drive), floppy disks or magnetic tapes.

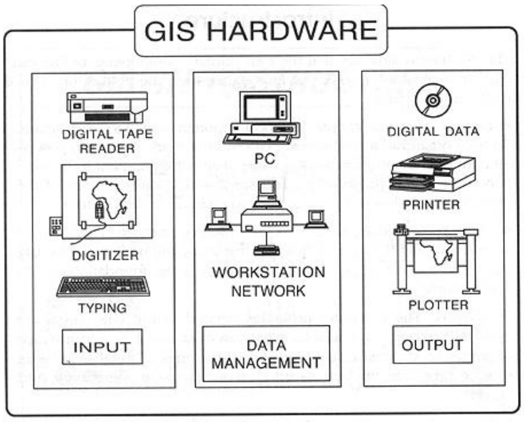


Figure (2-1) GIS Hardware [7].

2.2.2 Software.

GIS software provides the functions and tools needed to store, analyze, and display geographic information. Key software components are

- Tools for the input and manipulation of geographic information
- A database management system (DBMS)
- Tools that support geographic query, analysis, and visualization
- A graphical user interface (GUI) for easy access to tools

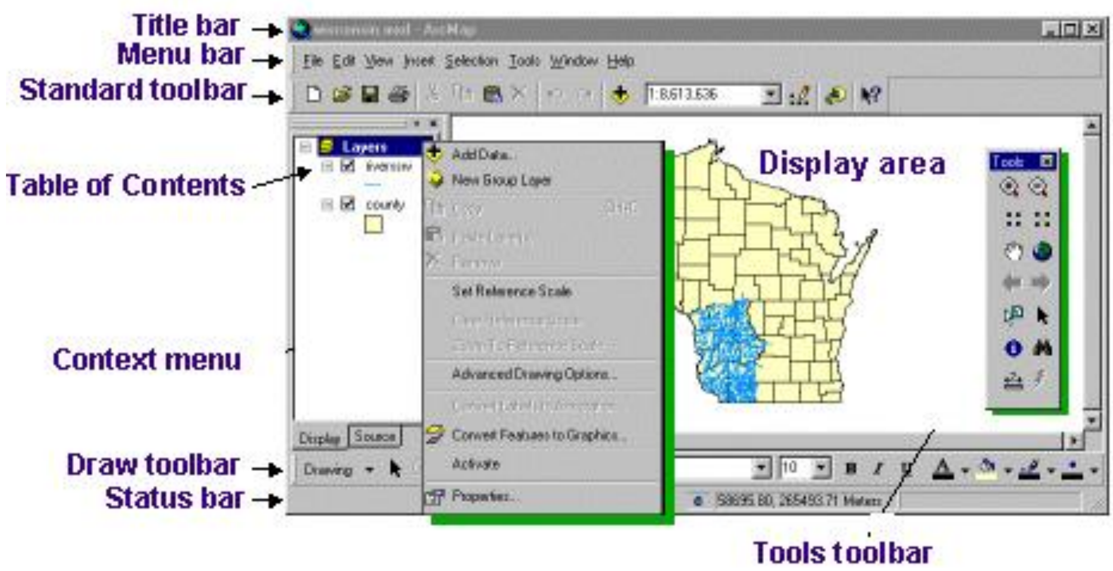


Figure (2-2) Gis Software .

2.2.3 Data.

Data is the core of any GIS. A geodatabase is a database that is referenced to locations on the earth. Geodatabases are grouped into two different types: vector and raster. Vector data is spatial data represented as points, lines and polygons. Raster data is cell-based data such as aerial imagery and digital elevation models. Coupled with this data is usually data known as attribute data. Attribute data generally defined as additional information about each spatial feature housed in tabular format. Documentation of GIS datasets is known as metadata .Types of data inside GIS are explained in an single section later[3].

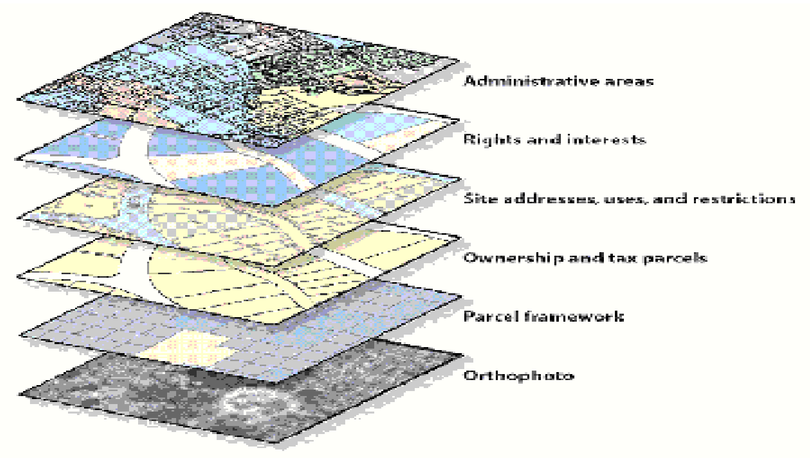


Figure (2-3) Data themes as layers[7].

2.2.4 People.

Well-trained GIS professionals knowledgeable in spatial analysis and skilled in using GIS software are essential to the GIS process. There are three factors to the people component: education, career path, and communication. The right education is key; taking the right combination of classes. Selecting the right type of GIS job is important. A person highly skilled in GIS analysis should not seek a job as a GIS developer if they haven't taken the necessary programming classes. Finally, continuous communication with other GIS professionals is essential for the exchange of ideas as well as a support community.

2.2.5 Methods

A neatly conceived implementation plan and business rules are the models and operating practices, are unique to each organization.

2.3 Sub-systems inside GIS

2.3.1 Cartographic display system.

This system allows users to select and extract a particular database or map output on the screen or printer etc. Cartography has been defined as the science, art and technology of making maps and its study as both scientific documents and works of art, or as the discipline dealing with the conception, production, dissemination and study of maps.

The relationship between GIS and Cartography, because the GIS includes ageographically referenced spatial data concept. However, the concept with cartography is not at all absolute from this perspective as any piece of data can be geographically located and entered in a database without necessarily coming from a map, though maps are a good source and the most common geographically referenced data for GIS.

Both cartography and GIS have to deal with geographic information and are communication instruments for decision taking, as both, with different capacities, allow for the treatment and analysis of geographic information. Regarding the dependence relationships GIS's are capable of generating outputs with all cartographic formalities, including media different from the traditional.

GIS arrived on the cartographic scene with a strong impact, where it is of some concern for the future of cartography, with the development of automated systems and the solutions of GIS.

2.3.2 Map digitising system

This system supports the process of converting the geographic features on an analog map into digital format using a digitizing tablet, or digitizer, which is connected to a computer. Features on a paper map are traced with a digitizer puck, a device similar to a mouse, and the x,y coordinates of these features are automatically recorded and stored as spatial data.

2.3.3 Database management system

This system has the ability to analyse the attribute data. Term "attribute" refer to qualities or characteristics of places with spatial and location information. Software, which provides cartographic display, map digitising and database query capabilities, are often referred to as automated mapping facilities management systems.

2.3.4 Spatial analysis system

Spatial analysis is the process of manipulating spatial information to extract new information and meaning from the original data. Usually spatial analysis is carried out with a Geographic Information System (GIS). A GIS usually provides spatial analysis tools for calculating feature statistics and carrying out geoprocessing activities as data interpolation. In hydrology, users will likely emphasize the importance of terrain analysis and the movement of water over and in the earth. In wildlife management, users are interested in analytical functions dealing with wildlife point locations and their relationship to the environment. Each user will have different things they are interested in depending on the kind of work they do.

2.3.5 Image processing system

It helps to analyse and classify the remotely sensed images (digital images) according to various classification techniques, which could be interpreted with the help of training data.

2.3.6 Statistical analysis system

This helps in statistical analysis of spatial and temporal data, which is required in scenario analyses.Inherent in GIS data is information on the attributes of features as well as their locations. This information are used to create maps that can be visually analyzed. Statistical analysis helps you extract additional information from your GIS data that might not be obvious simply by looking at a map information such as how attribute values are distributed, whether there are spatial trends in the data, or whether the features form spatial patterns. Unlike query functions such as identify or selection, which provide information about individual features statistical analysis reveals the characteristics of a set of features as a whole.

Uses of statistical analysis

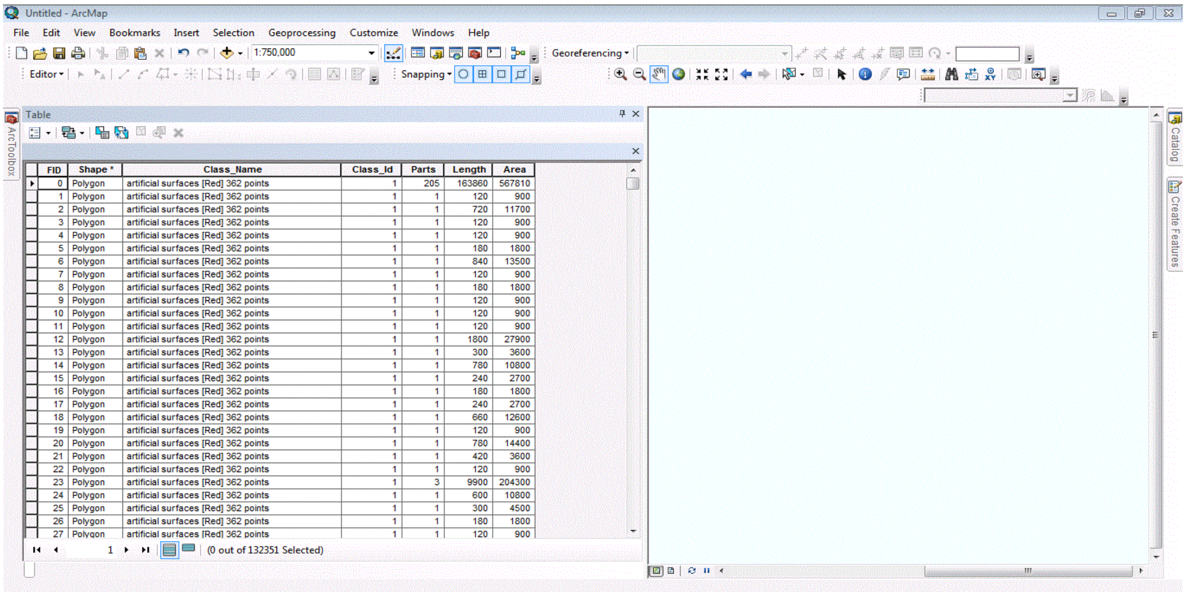
Statistical analysis is often used to explore your data, for example, to examine the distribution of values for a particular attribute or to spot outliers (extreme high or low values). Having this information is useful when defining classes and ranges on a map, when reclassifying data, or when looking for data errors.

Another use of statistical analysis is to summarize data. Often this is done for categories, such as calculating the total area in each land use category. You can also create spatial summaries, such as calculating the average elevation for each watershed. Summary data is useful for gaining a better understanding of conditions in a study area.

2.4 Types of data in GIS

2.4.1 Attribute data

A database or tabular file containing information about a set of geographic features, usually arranged so that each row represents a feature and each column represents one feature attribute. In raster datasets, each row of an attribute table corresponds to a certain zone of cells having the same value. In a GIS, attribute tables are often joined or related to spatial data layers, and the attribute values they contain can be used to find, query, and symbolize features or raster cells[2].



FID	Shape *	Class_Name	Class_Id	Parts	Length	Area
0	Polygon	artificial surfaces [Red] 362 points	1	205	163860	567810
1	Polygon	artificial surfaces [Red] 362 points	1	1	120	900
2	Polygon	artificial surfaces [Red] 362 points	1	1	720	11700
3	Polygon	artificial surfaces [Red] 362 points	1	1	120	900
4	Polygon	artificial surfaces [Red] 362 points	1	1	120	900
5	Polygon	artificial surfaces [Red] 362 points	1	1	180	1800
6	Polygon	artificial surfaces [Red] 362 points	1	1	840	13500
7	Polygon	artificial surfaces [Red] 362 points	1	1	120	900
8	Polygon	artificial surfaces [Red] 362 points	1	1	180	1800
9	Polygon	artificial surfaces [Red] 362 points	1	1	120	900
10	Polygon	artificial surfaces [Red] 362 points	1	1	120	900
11	Polygon	artificial surfaces [Red] 362 points	1	1	120	900
12	Polygon	artificial surfaces [Red] 362 points	1	1	1800	27900
13	Polygon	artificial surfaces [Red] 362 points	1	1	300	3600
14	Polygon	artificial surfaces [Red] 362 points	1	1	780	10800
15	Polygon	artificial surfaces [Red] 362 points	1	1	240	2700
16	Polygon	artificial surfaces [Red] 362 points	1	1	180	1800
17	Polygon	artificial surfaces [Red] 362 points	1	1	240	2700
18	Polygon	artificial surfaces [Red] 362 points	1	1	660	12600
19	Polygon	artificial surfaces [Red] 362 points	1	1	120	900
20	Polygon	artificial surfaces [Red] 362 points	1	1	780	14400
21	Polygon	artificial surfaces [Red] 362 points	1	1	420	3600
22	Polygon	artificial surfaces [Red] 362 points	1	1	120	900
23	Polygon	artificial surfaces [Red] 362 points	1	3	9900	204300
24	Polygon	artificial surfaces [Red] 362 points	1	1	600	10800
25	Polygon	artificial surfaces [Red] 362 points	1	1	300	4500
26	Polygon	artificial surfaces [Red] 362 points	1	1	180	1800
27	Polygon	artificial surfaces [Red] 362 points	1	1	120	900

Figure (2-4) Attribute table in ArcGIS[2].

2.4.2 Vector and raster data

Vector data are stored as a series of X,Y coordinate pairs inside the computer's memory. Vector data is used to represent points, lines and areas[10] **.**

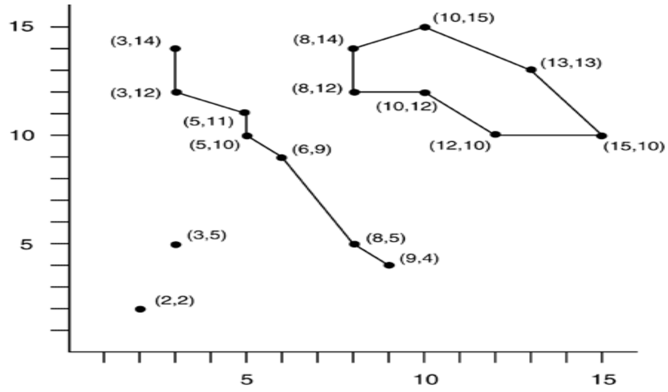


Figure (2-5)Vector data[10].

Advantages of vector type data

- The vector type data uses less storage space.
- It supports greater precision in the computation and processing of spatial features.

Raster data are stored as a grid of values. There are many satellites circling the earth and the photographs they take are a kind of raster data that can be viewed in a GIS. One important difference between raster and vector data is that if you zoom in too much on a raster image, it will start to appear 'blocky'.

Advantages of raster data type

- Provides better representation of continuous surfaces.
- Map overlays are efficiently processed if thematic layers are coded in a simple raster structure.
- Because the raster grid defines units or pixels that are constant in shape, spatial relationships among pixels are constant and easily traceable.

Figure(2-6) Raster data by satalite, the same area to the left with zoom in.

2.4.3 Other raster data systems

- Digital Elevation Model (DEM)

A DEM is a set of digital topographic data that can be developed from contours of an area. It is done by the converting the vector contour file to rastr.

- Triangular Irregular Network (TIN)

A TIN is an organisation of spatial information based on a set of irregularly shaped triangles that form a connected network. TIN is used to efficiently organise surface data with minimal redundancy[3].

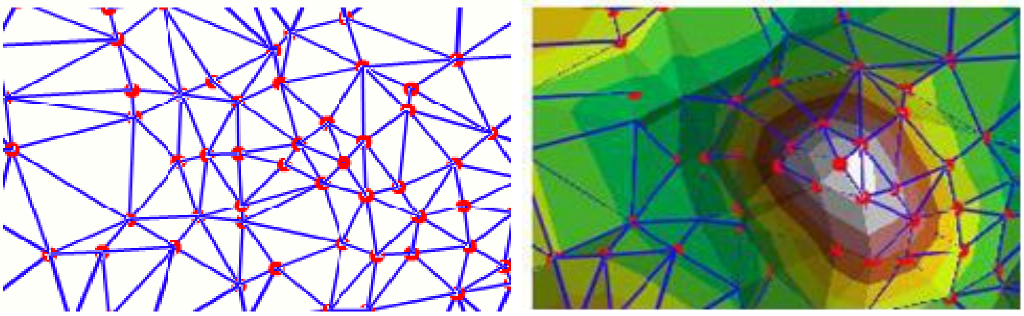


Figure (2-7) Nodes and edges of a TIN (left) and the nodes, edges, and faces of a TIN (right).

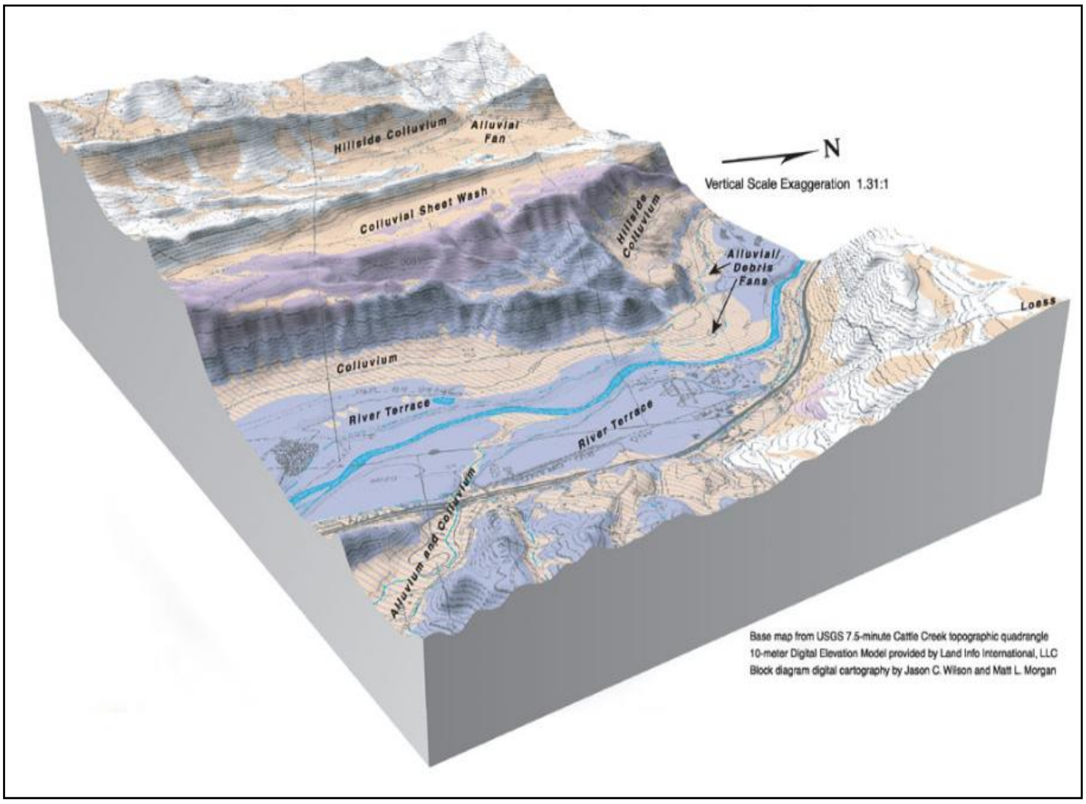
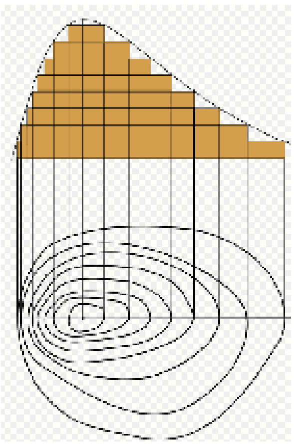


Figure (2-8) DEM

- Digital Line Graph (DLG)

The data are vectors based in the form of digitised lines. DLGs are available for several categories of data including contours, roads and rivers.



Figure(2-9) Contour Lines.

2.5 Working of GIS

GIS stores data about as layers and it can be linked together by geography. This concept has assisted in solving many real-world. The working of a GIS can be summarised as:

- Relating information from different sources
- Geographic references / locations
- Data capture
- Data integration
- Projection and registration
- Data structures
- Data modelling

2.5.1 Relating information from different sources

The ability of GIS to relate information from disparate sources helps in planning and management of natural resources. A GIS can be used for converting existing digital information, into forms, which it can recognise and use. For example, digital satellite images can be analysed to produce a thematic layer of digital information about vegetation. Additionally, existing tabular data such as census can be converted to map-like format. For the data to be usable, it needs to be geo-referenced to the map in some way.

2.5.2 Geographic References

Geographic information contains either an explicit geographic reference, such as a latitude and longitude or national grid coordinate, or an implicit reference such as an address, postal code, census tract name, forest stand identifier, or road name. An automated process called geocoding is used to create explicit geographic references (multiple locations) from implicit references (descriptions such as addresses). These geographic references allow you to locate features, such as a business or forest stand, and events, such as an earthquake, on the earth's surface for analysis.

2.5.3 Data capture

The process of getting data into a digital format recognised by the GIS is known as data capture . Data on existing paper maps can be digitised or hand traced using a mouse in order to collect the coordinates of the features. Electronic scanning devices are the other options for the data capture.

2.5.4 Data Integration

A GIS stores information as a collection of thematic layers, which are linked together by geography. Underlying these layers are associated tables of spatial and descriptive attributes that describe the geographic features.

2.5.5. Projection and Registration

All the information that is obtained from various disparate sources has to be converted to consistent spatial references before using in GIS. This process aligns all the data layers by establishing a consistent coordinate system for all the data layers. Before data is analysed, in most of the GIS projects, projection of the map is done. Projection, one of the fundamentals of mapmaking, is the mathematical method of transferring information from the earth's three-dimensional surface to two-dimensional plate. Map projections, will result in the distortion of one or more of these properties: shape, area, distance and direction. Some of the projections that are used are Universal Transverse Mercator (UTM), Lambert Conformal Conic, etc.

2.5.6 Data structures

Geographic information systems work with two fundamentally different types of geographic "spatial" models, the "vector" model and the "raster" model, as mentioned.

2.6. GIS tasks

General-purpose geographic information systems essentially achieves six processes or tasks: Input , Manipulation , Management , Query and Analysis and Visualisation.

2.6.1 Input

Before geographic data can be used in a GIS, the data must be converted into a suitable digital format. The process of converting data from paper maps into computer files is called *digitizing*. Modern GIS technology can automate this process fully for large projects using scanning technology; smaller jobs may require some manual digitising (using a digitising table). Today many types of geographic data already exist in GIS-compatible formats. These data can be obtained from data suppliers and loaded directly into a GIS.

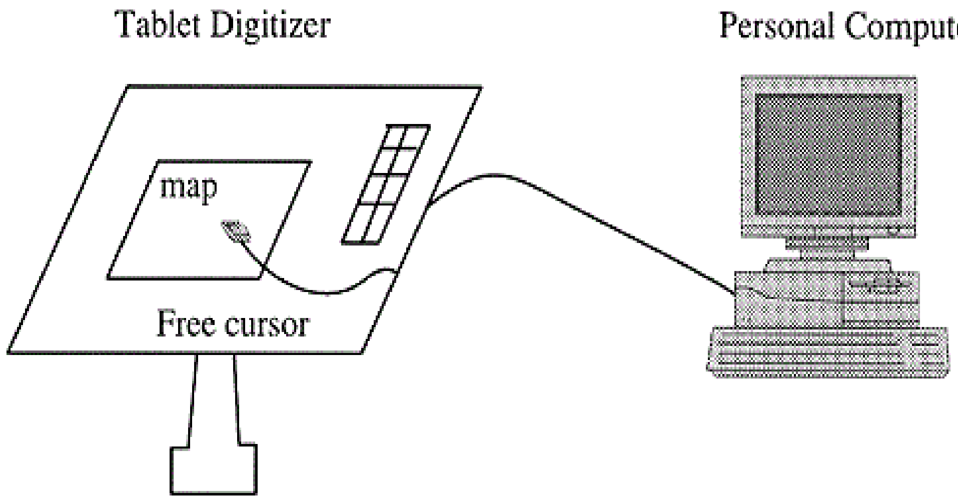


Figure (2-10) Tablet Digitizer .

2.6.2 Manipulation

It is likely that data types required for a particular GIS project will need to be transformed or manipulated in some way to make them proper with user's system. For example, geographic information is available at different scales (detailed street centreline files; less detailed census boundaries; and postal codes at a regional level). Before this information can be integrated, it must be transformed to the same scale. This could be a temporary transformation for display purposes or a permanent one required for analysis. GIS technology offers many tools for manipulating spatial data and for weeding out unnecessary data.

2.6.3 Management

For small GIS projects, it may be sufficient to store geographic information as simple files. However, when data volumes become large and the number of data users becomes more than a few, it is often best to use a database management system (DBMS) to help store, organise, and manage data. DBMS is nothing more than computer software for managing a database.

There are many different designs of DBMS's, but in GIS the relational design has been the most useful. In the relational design, data are stored conceptually as a collection of tables. Common fields in different tables are linked together. This surprisingly simple design has been so widely used primarily because of its flexibility, with very wide deployment in applications both within and without GIS.

2.6.4 Query and Analysis

Once the geographic information/data is entered into GIS, simple queries such as ownership of the land parcel, distance between two places, zoning for industrial use, and analytical questions such as, location of sites suitable for building new houses, dominant vegetation and soil types, traffic control by ring roads, flyover and sub urban transit system, can be done and results obtained quickly. Processes like selection are used.

2.6.5 Proximity Analysis

This can be done to find out various elements within a desired distance from any object. The queries may be like this:

- Number of plants / trees within 100 m of water source.
- Total number of users within 10 km of a water source.

To answer such questions, GIS technology uses a process called buffering to determine the proximity relationship between features.

2.6.6 Overlay Analysis

The integration of different data layers involves a process called overlay. This could be a visual operation, but analytical operations require one or more data layers to be joined physically. This overlay, or spatial join, can integrate data on soils, slope, and vegetation.

2.6.7 Visualisation

For many types of geographic operation the end result is best visualised as a map or graph. Maps are very efficient at storing and communicating geographic information. While cartographers have created maps for many years, GIS provides new and exciting tools to extend the art and science of cartography. Map displays can be integrated with reports, three-dimensional views, photographic images, and other output such as multimedia.

2.7 Important sources of data for GIS

2.7.1 Land Surveying

Surveying or land surveying is the technique, profession, and science of accurately determining the terrestrial or three-dimensional position of points and the distances and angles between them, commonly practiced by licensed surveyors, and members of various building professions. These points are usually on the surface of the Earth, and they are often used to establish land maps and boundaries for ownership, locations (building corners, surface location of subsurface features) or other governmentally required or civil law purposes (property sales).To accomplish their objective, surveyors use elements of mathematics (geometry and trigonometry), physics, engineering and law[3].

An alternative definition, from the American Congress on Surveying and Mapping (ACSM), is the science and art of making all essential measurements to determine the relative position of points or physical and cultural details above, on, or beneath the surface of the Earth, and to depict them in a usable form, or to establish the position of points or details.

Furthermore, as alluded to above, a particular type of surveying known as "land surveying" (also per ACSM) is the detailed study or inspection, as by gathering information 24 through observations, measurements in the field, questionnaires, or research of legal instruments, and data analysis in the support of planning, designing, and establishing of property boundaries. It involves the re-establishment of cadastral surveys and land boundaries based on documents of record and historical evidence, as well as certifying surveys (as required by statute or local ordinance) of subdivision plats or maps, registered land surveys, judicial surveys, and space delineation. Land surveying can include associated services such as mapping and related data accumulation, construction layout surveys, precision measurements of length, angle, elevation, area, and volume, as well as horizontal and vertical control surveys, and the analysis and utilization of land survey data.

Surveyors use various tools to do their work successfully and accurately, such as total stations, robotic total stations, GPS receivers, prisms, 3D scanners, radio communicators, handheld tablets, digital levels, and surveying software.

Surveying has been an essential element in the development of the human environment since the beginning of recorded history (about 6,000 years ago). It is required in the planning and execution of nearly every form of construction. Its most familiar modern uses are in the fields of transport, building and construction, communications, mapping, and the definition of legal boundaries for land ownership.

Figure(2-11) Land Surveying

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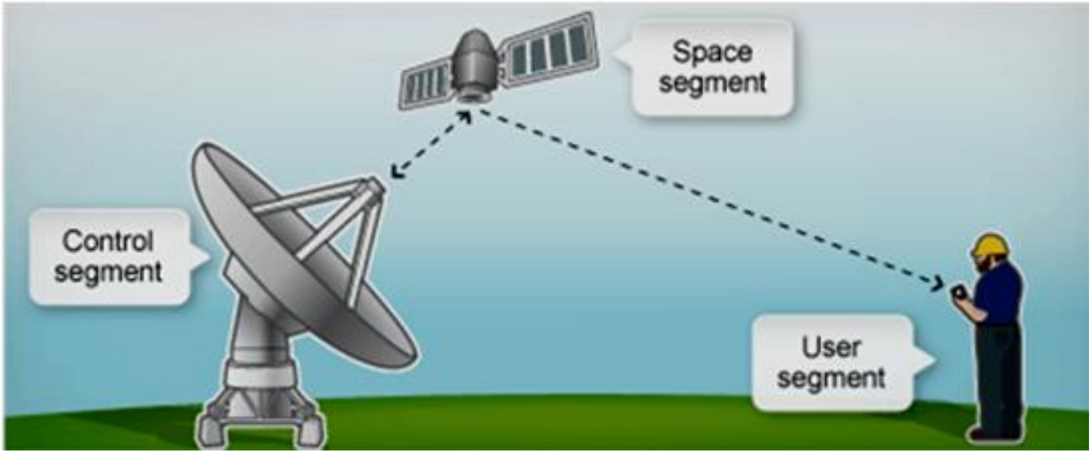
2.7.2 Global Positioning System

The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. The system provides critical capabilities to military, civil and commercial users around the world. It is maintained by the United States government and is freely accessible to anyone with a GPS receiver.

The GPS project was developed in 1973 to overcome the limitations of previous navigation systems, integrating ideas from several predecessors, including a number of classified engineering design studies from the 1960s. GPS was created and realized by the U.S. Department of Defense (DoD) and was originally run with 24 satellites. It became fully operational in 1995.

In addition to GPS, other systems are in use or under development. The Russian Global Navigation Satellite System (GLONASS) was developed contemporaneously with GPS, but suffered from incomplete coverage of the globe until the mid-2000s. There are also the planned European Union Galileo positioning system, India's Indian Regional Navigational Satellite System and Chinese Compass navigation system.

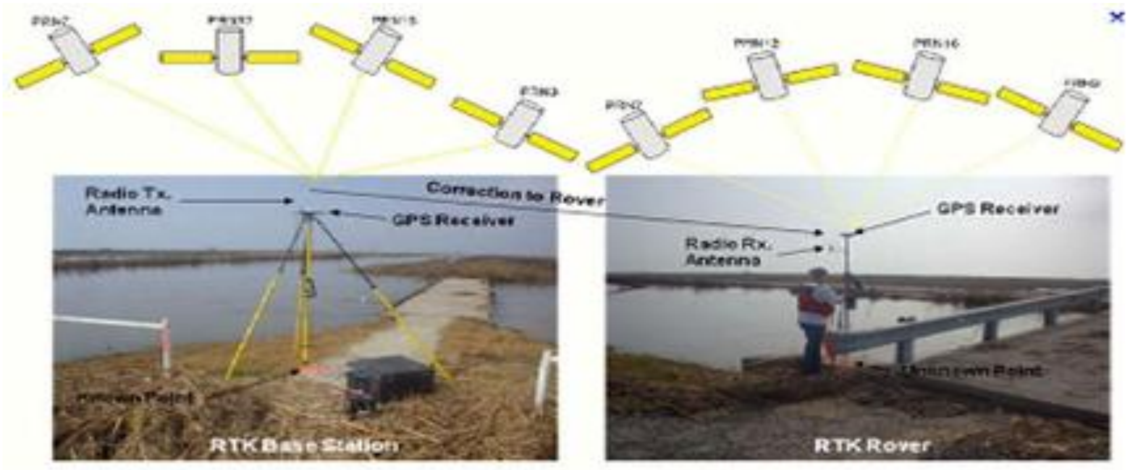
The current GPS consists of three major segments. These are the space segment (SS), a control segment (CS), and a user segment (US). The U.S. Air Force develops, maintains, and operates the space and control segments. GPS satellites broadcast signals from space, and each GPS receiver uses these signals to calculate its three-dimensional location (latitude, longitude, and altitude) and the current time.



Figure(2-12) GPS Segments

The space segment is composed of 24 to 32 satellites in medium Earth orbit and also includes the payload adapters to the boosters required to launch them into orbit.

The control segment is composed of a master control station, an alternate master control station, and a host of dedicated and shared ground antennas and monitor stations. The user segment is composed of hundreds of thousands of U.S. and allied military users of the secure GPS Precise Positioning Service, and tens of millions of civil, commercial, and scientific users of the Standard Positioning Service .



Figure(2-13) Surveying With GPS.

2.7.3 Photogrammetry

Photogrammetry is the science, technology and art of obtaining reliable information from noncontact imaging and other sensor systems about the Earth and its environment, and other physical objects and processes through recording, measuring, analysing and representation. Photogrammetry uses methods from many disciplines, including optics and projective geometry.

The 3-D co-ordinates define the locations of object points in the 3-D space. The image co-ordinates define the locations of the object points' images on the film or an electronic imaging device. The exterior orientation of a camera defines its location in space and its view direction. The inner orientation defines the geometric parameters of the imaging process. This is primarily the focal length of the lens, but can also include the description of lens distortions. Further additional observations play an important role: With scale bars, basically a known distance of two points in space, or known fix points, the connection to the basic measuring units is created.Each of the four main variables can be an input or an output of a photogrammetric method.

Photogrammetry has been defined by the American Society for Photogrammetry and Remote Sensing (ASPRS) as the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena.

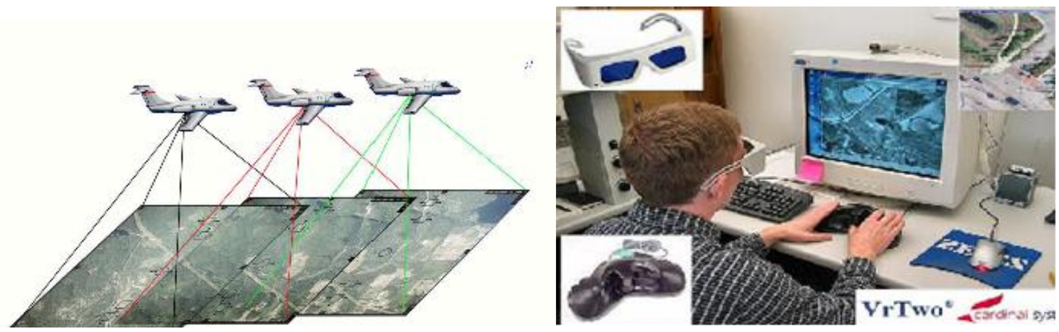


Figure (2-14) Photogrammetry System.

Photogrammetry is used in different fields, such as topographic mapping, architecture, engineering, manufacturing, quality control, police investigation, and geology, as well as by archaeologists to quickly produce plans of large or complex sites and by 28 meteorologists as a way to determine the actual wind speed of a tornado where objective weather data cannot be obtained.

2.7.4 Remote sensing

Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information.

.

In much of remote sensing, the process involves an interaction between incident radiation and the targets of interest. This is exemplified by the use of imaging systems where the following seven elements are involved. Note, however that remote sensing also involves the sensing of emitted energy and the use of non-imaging sensors[4].

1. Energy Source or Illumination (A) – the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.

2. Radiation and the Atmosphere (B) – as the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.

3. Interaction with the Target (C) - once the energy makes its way to the target through theatmosphere, it interacts with the target depending on the properties of both the target and the radiation.

4. Recording of Energy by the Sensor (D) - after the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.

5. Transmission, Reception, and Processing (E) - the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).

6. Interpretation and Analysis (F) - the processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.

7. Application (G) - the final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

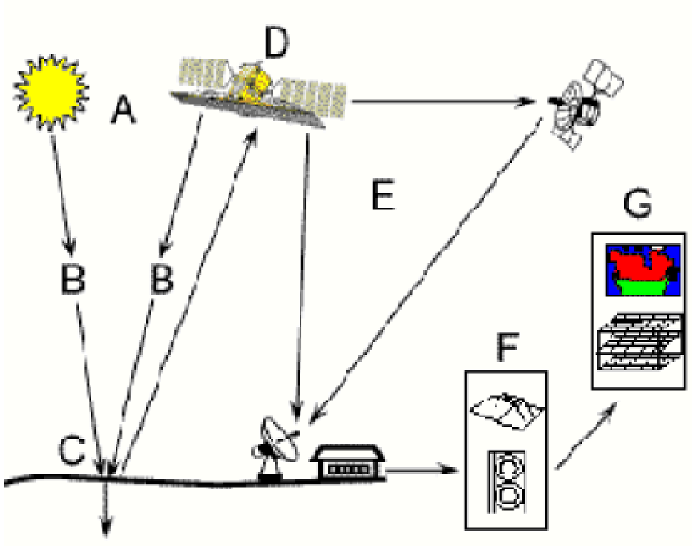


Figure (2-15) Remote Sensing Process[4].

2.8 Applications of GIS

1. Agriculture
2. Forestry & Wildlife Management
3. National, State, County, Regional, Local mapping and geographic inventory
4. Archaeology
5. Geology
6. Oil and gas exploration and production
7. Municipal Applications
8. Streets
9. Properties/Cadastre
10. Facilities
11. Utilities
12. Water, Sewer, Storm Sewer
13. Environment

14. Areas/Districts Utility Applications

15. Electric

16. Gas

17. Telephone

18. Cable Television

2.9 Coordinate systems

A basic principle in GIS is that map layers to be used together must align spatially. Obvious mistakes can occur if they do not. GIS users typically work with map features on a plane . These maps features represent spatial features on the Earth's surface. The locations of map features are based on a plane coordinate system expressed in x- and y- coordinates, whereas the locations of spatial features on the Earth's surface are based on a geographic coordinate values. A map projection bridges the two types of coordinate systems. The process of projection transforms the Earth;s surface to a plane, and the outcomeis a map projection, ready to be used for a plane or projected coordinate system[5].

2.9.1 Geographic coordinate system

The geographic coordinate system is the location reference system for spatial features on the Earth's surface (Figure). The geographic coordinate system is defined by longitude and latitude. Both longitude and latitude are angular measures : longitude measures the angle east or west from the prime meridian, and altitude measure the angle north or south of equatorial plane.

Figure (2-16) Geographic Rrepresentation [5].

2.9.2 Projected coordinate systems

A projected coordinate systems, also called a plane coordinate system , is built on a map projection. Projected coordinate systems and map projections are often used interchangeably. For example, the Lambert conformal conic is a map projection but it can also refer to a coordinate system. In practice, however, projected coordinate systems are designed for detailed calculations and positioning, and are typically used in large-scale mapping such as at scale of 1:50000. Accuracy in a feature's location and its relative position to other features is therefore a key consideration in the deisgn of a projected coordinate system.

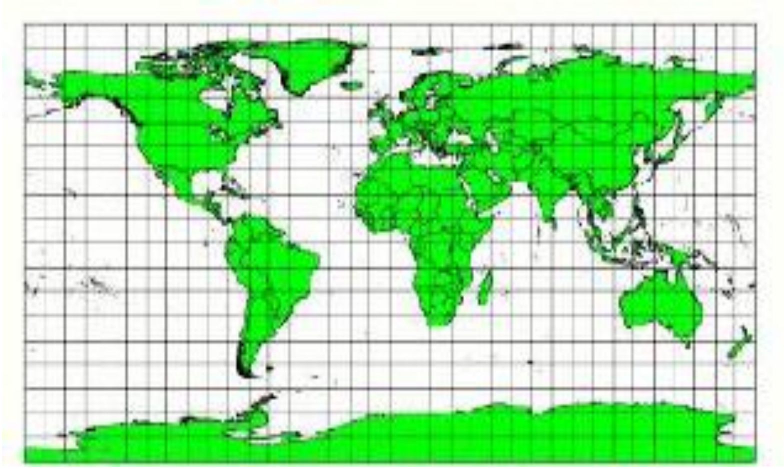


Figure (2-17) Projected Representation [5].

2.10 Map Production

Map production is the process of arranging map elements on a sheet of paper in a way that any person can understand what it is mean. Maps are usually produced for presentations and reports where the audience or reader is a politician, citizen or a learner with no professional background in GIS. Because of this, a map has to be effective in communicating spatial information. Main elements of a map are the title, map body, legend, north arrow, scale bar, acknowledgement, and map border.

Other elements that might be added are e.g. grid, or name of the map projection and coordinate system. These elements help the map reader to interpret the information shown on the map. The map body is the most important part of the map because it contains the map information. The other elements support the communication process and help the map reader understand the map topic. For example, the title describes the subject matter and the legend relates map symbols to the mapped data[9].

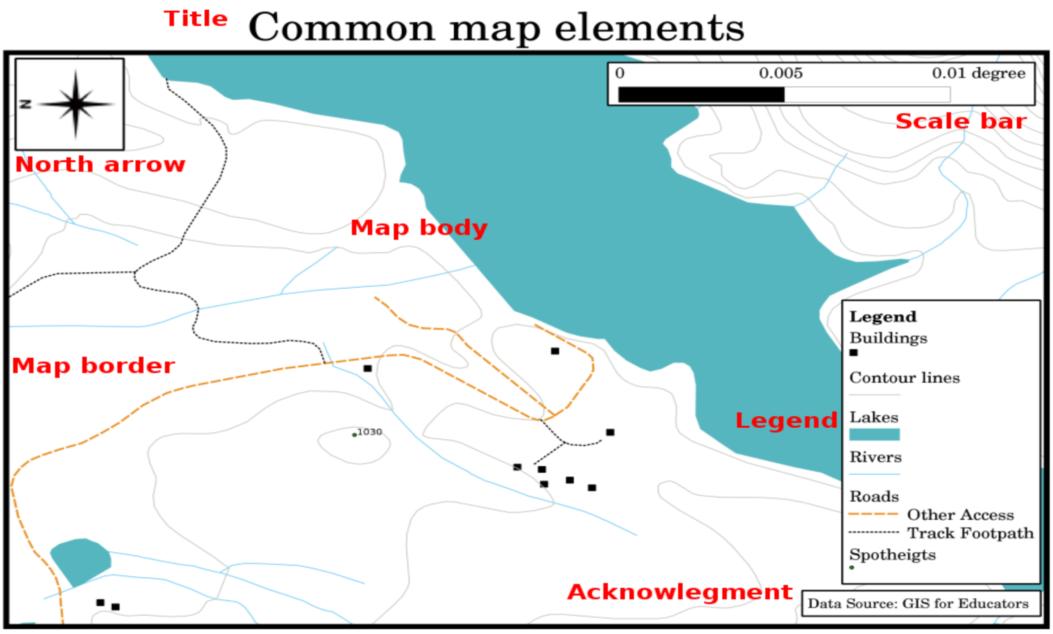


Figure (2-18) Common Map Elements[9]

2.10 .1 Title

The map title is very important because it is usually the first thing a reader will look at on a map. It should be short but give the reader a first idea of what the map is about.

2.10 .2 Map Border

The map border is a line that defines exactly the edges of the area shown on the map. When printing a map with a grid (which will be shown down), the coordinate information of the grid lines along the border lines will be found.

2.10 .3 Map Legend

A map is a simplified representation of the real world and map symbols are used to represent real objects. Without symbols, maps wouldn't be understood. To ensure that a person can correctly read a map, a map legend is used to provide a key to all the symbols used on the map. It is like a dictionary that allows you to understand the meaning of what the map shows. A map legend is usually shown a little box in a corner of the map. It contains icons, each of which will represent a type of feature. For example, a house icon will show you how to identify houses on the map.

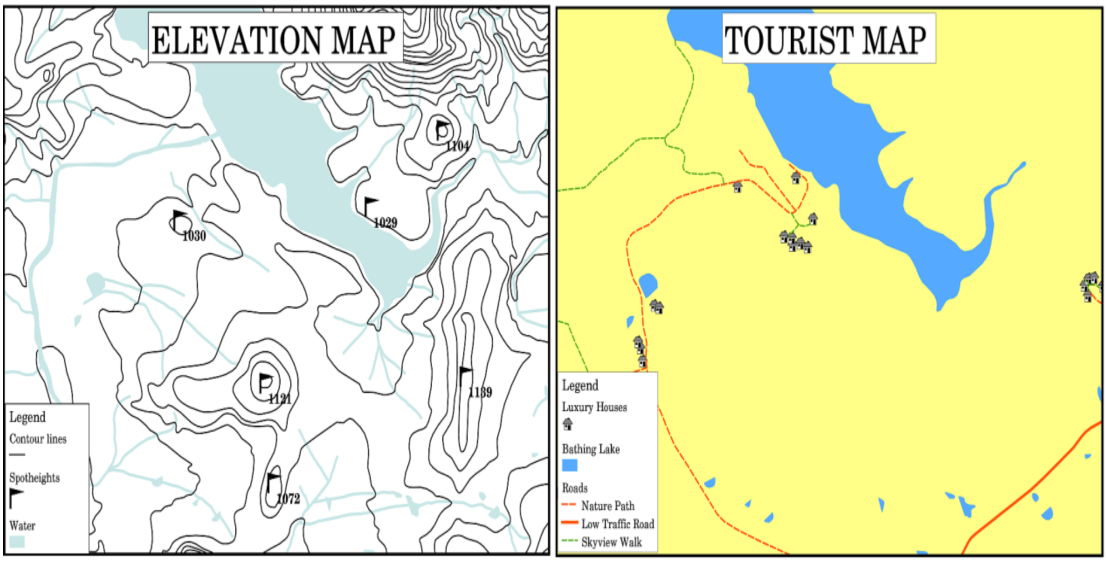


Figure (2-19) Two maps from the same area, both with a water body in the background but with different themes, map symbols and colors in the legend [6].

You can also use different symbols and icons in your legend to show different themes.

2.10 .4 North arrow

A north arrow is a figure displaying the main directions, **North**, **South**, **East** and **West**. On a map it is used to indicate the direction of North.

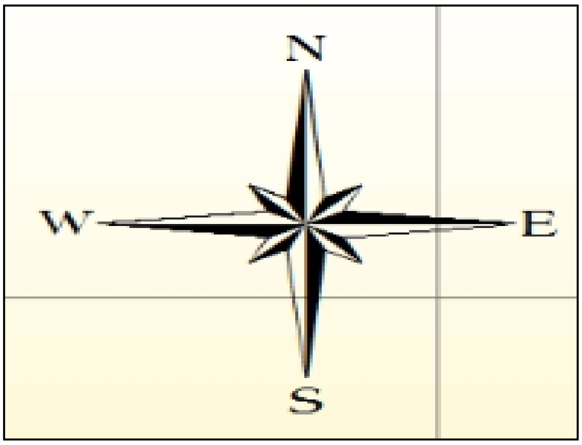


Figure (2-20) North Arrow

2.10 .5 Scale

The scale of a map, is the value of a single unit of distance on the map, representing distance in the real world. The values are shown in map units (meters, feet or degrees). The scale can be expressed in several ways, for example, in words, as a ratio or as a graphical scale bar.

a) (1 centimeter represents 250 meters)

b) 1: 25 000

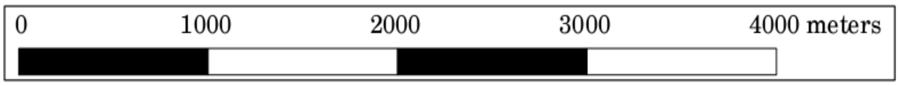
c)


Figure (2-21) Scale Expressions .

2.10 .6 Acknowledgment

In the acknowledgment area of a map it is possible to add text with important information. For example information about the quality of the used data . or how the map was produced or by whom etc.

2.10 .7 Grid

The grid is a network of lines overlain on a map to make spatial orientation easier for the reader. The lines can be used as a reference. As an example, the lines of a grid can represent the earth's parallels of latitude and meridians of longitude. When you want to refer to a special area on a map during your presentation or in a report you could say: 'the houses close to latitude 26.04 / longitude -32.11 are often exposed to flooding during January and February'.

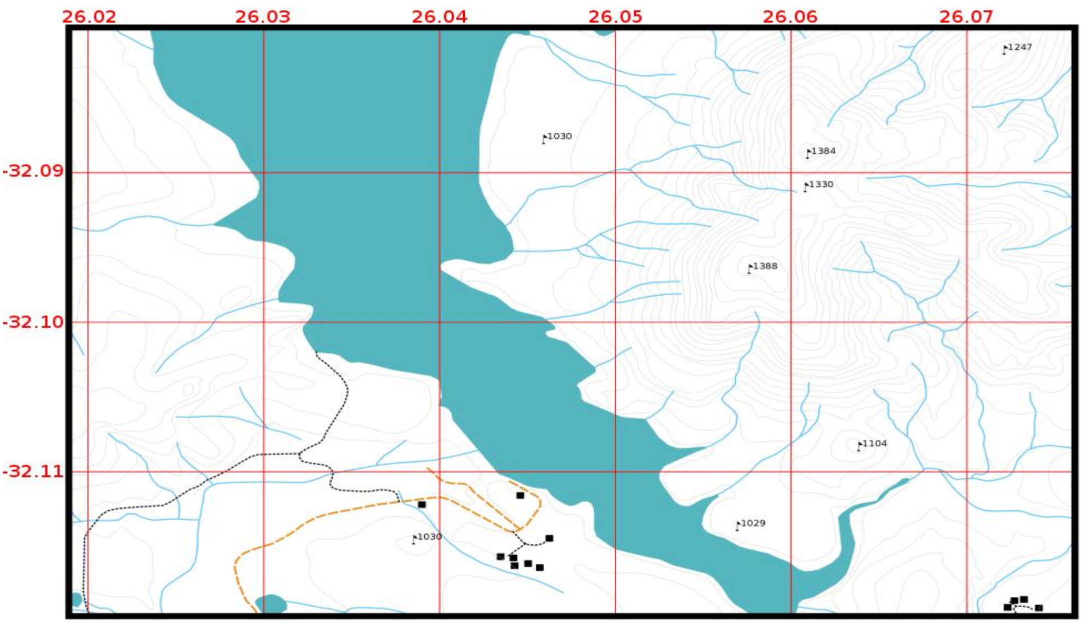


Figure (2-22) Grid

2.10 .8 Name of the map projection

A map projection tries to represent the 3-dimensional Earth with all its features like houses, roads or lakes on a flat sheet of paper. This is very difficult as you can imagine, and even after hundreds of years there is no single projection that is able to represent the Earth perfectly for any area in the world. Every projection has advantages and disadvantages

.

To be able to create maps as precisely as possible, people have studied, modified, and produced many different kinds of projections. In the end almost every country has developed its own map projection with the goal of improving the map accuracy for their territorial area.

Figure Map Projection 1:

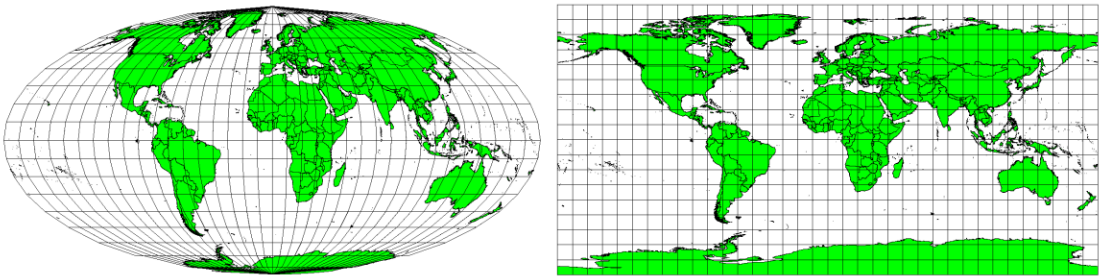


Figure (2-23) The world in different projections. A Mollweide Equal Area projection left, a Plate Carree Equidistant Cylindrical projection on the right[9].

2.11 About QGIS

QGIS is an Open Source Geographic Information System. The project was born in May of 2002 and was established as a project on SourceForge in June of the same year. There was worked hard to make GIS software (which is traditionally expensive commercial software) available prospect for anyone with basic access to a Personal Computer. QGIS currently runs on most Unix platforms, Windows, and OS X. QGIS is developed using the Qt toolkit (http://qt.io) and C++. This means that QGIS feels snappy to use and has a pleasing, easy to use graphical user interface

.

QGIS aims to be an easy to use GIS, providing common functions and features. The initial goal was to provide a GIS data viewer. QGIS has reached that point in its evolution and is being used by many for their daily GIS data viewing and editing needs. QGIS supports a number of raster and vector data formats, with new support easily added using the plugin architecture[8].

QGIS is released under the GNU Public License (GPL) Version 2. Developing QGIS under this license means that you can (if you want to) inspect and modify the source code and guarantees that you will always have access to a GIS program that is free of cost and can be freely modified.

Supported raster formats include:

- Grass
- USGS DEM
- ArcInfo binary grid
- ArcInfo ASCII grid
- ERDAS Imagine
- SDTS
- GeoTiff
- Tiff with world file

Supported vector formats include:

- ESRI Shapefiles
- PostgreSQL/PostGIS
- GRASS
- Spatialite
- Other OGR supported formats

DIGITAL ELEVATION MODEL

3.1 Definition of DEM

3.2 Types of DEM

3.3 DEM's Applications

3.4 Photogrammetric DTM

3.5 Satellite DTM (remotely sensed data)

3.6 Global Satellite DTMs

Digital Elevation Model

3.1 Definition of DEM

Digital Elevation Models (DEM) is the representation of continuous elevation values over a topographic surface by a regular array of z-values, referenced to a common datum. DEMs are typically used to represent terrain relief. **[11]**

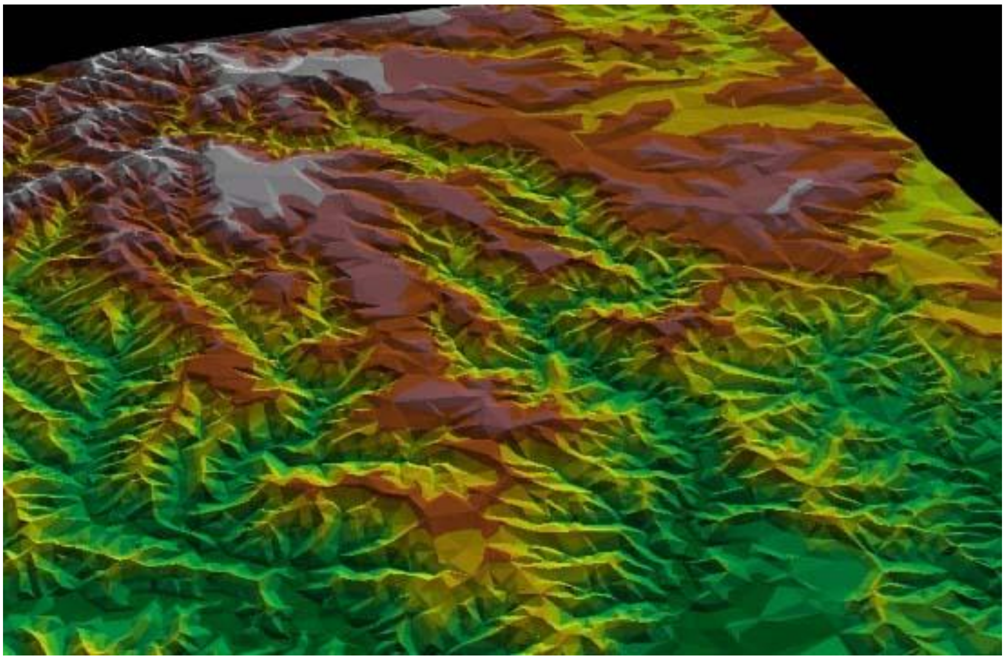


Figure (3-1) DTM [11].

3.2 Types of DEM

Digital elevation model can be edited to generate two types of DEMs, they are: digital terrain model (DTM) ,and digital surface model (DSM).

1) **Digital Terrain Model** : representation of a bare-earth model that contains elevations of natural terrain features where vegetation, buildings and other non-ground objects have been digitally removed.

2) **Digital Surface Model** : which contains elevations of natural terrain in addition to top of buildings, trees and any other objects. **[11]**

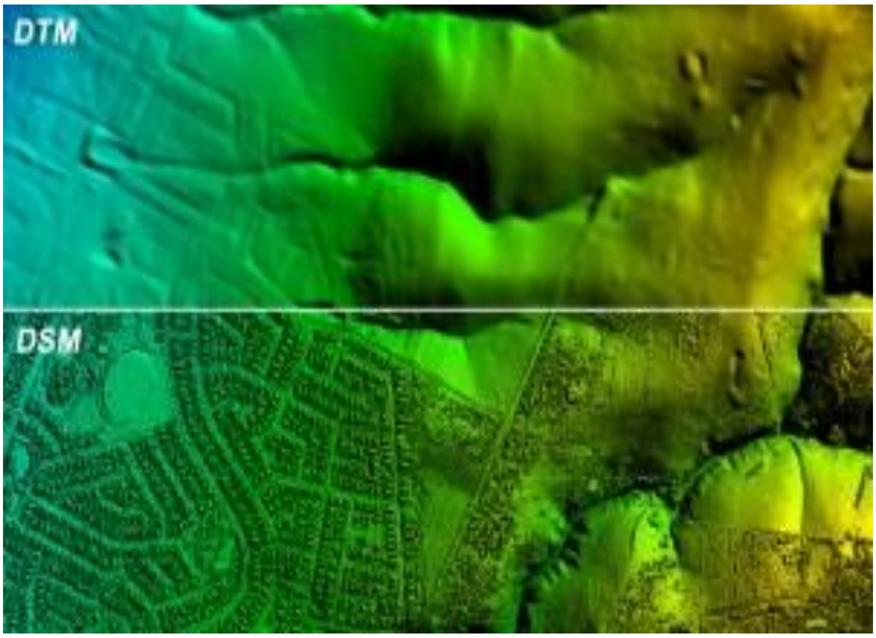


Figure (3-2) DTM , DSM [11].

3.3 DEM's Applications

Digital Elevation Models have a very wide range of applications. The most important application areas of DEMs in civil engineering are: [11]

1) Slope steepness maps, showing the steepness of slopes in degrees, percentages, or radians for each location (pixel).

2) Slope direction maps (also called slope aspect maps), showing the orientation or compass direction of slopes (between 0˚-360˚).

3) Slope convexity/concavity maps, showing the change of slope angles within a short distance. From these maps you can see if slopes are straight, concave or convex in form.
4) Three dimensional views for terrains.

5) Cross-sections indicating the altitude of the terrain along a line and represented in a graph (distance against altitude).

6) Volume maps (or cut-and-fill maps), generated by overlaying two DEMs from different periods. This allows you to quantify the changes in elevation that took place as a result of slope flattening, road construction, landslides etc.

7) Creation of Ortho-images from aerial photographs or satellite images. With the help of DEMs, aerial photographs and satellite images can be corrected for tilt distortion and relief displacement.

3.4 Photogrammetric DTM

Photogrammetric procedures for digital terrain model (DTM) data determination fall into two of categories: Automatic and manual [12]. Automatic collection of elevation data by digital correlation from digitized film or digital imagery is called image matching.

Image matching is a technique, in order to determine identical points in one or several images, to determine an objects position in an image or to reconstruct an object. The following procedures are followed to apply image matching:

1) Define the window **A** around the pixel in the first image e.g. 3X3.

2) Define the search area in the second image.

3) Find the correlation coefficient between the pixel and its window in the first image and with a window **B** with same size around each pixel in the search area in the second image.

4) From all calculated correlation coefficients select the pixel with the best correlation coefficient. This pixel is the pixel we need to find.

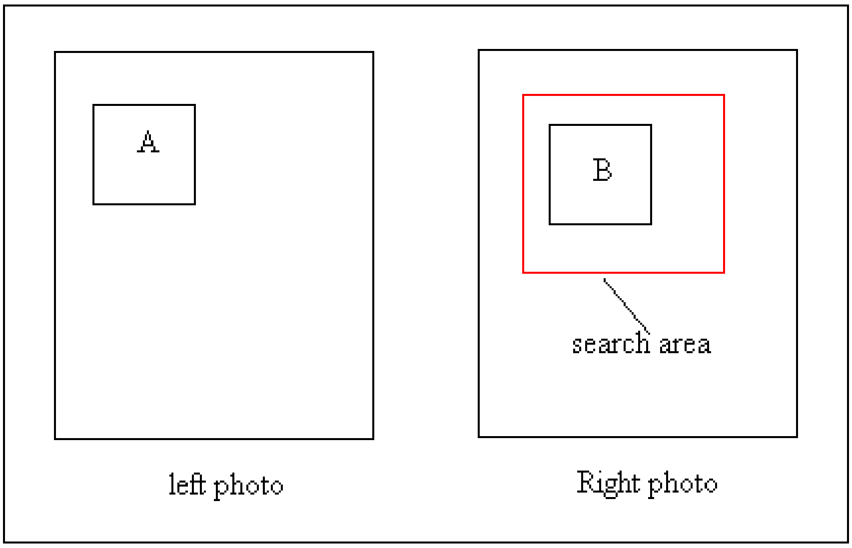


Figure (3-3): image matching between two images[12].

3.4.1 Techniques of image matching

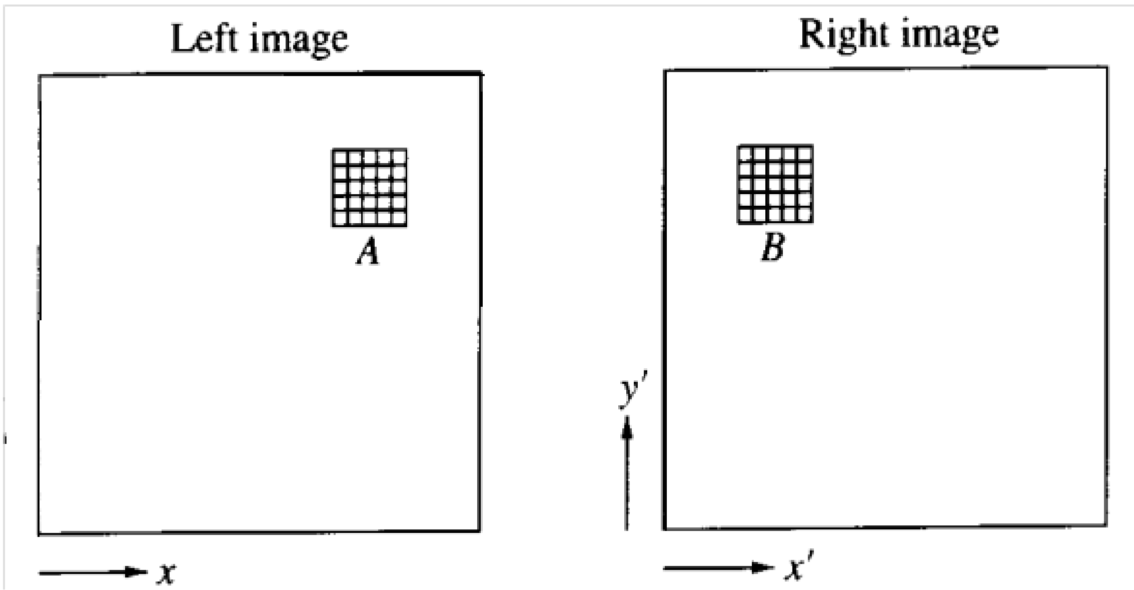
Different techniques are applied in image matching for automatic DTM collection, these methods are:

1) Area Based matching: It deals with gray values, respectively colors, this technique simple and easy. It could be done by many methods explained as follows:[12]

1- linear cross correlation.

$$c_{11} = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left[(A_{ij}-\bar{A})(B_{ij}-\bar{B})\right]}{\sqrt{\left[\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij}-\bar{A})^{2}\right]\left[\sum_{i=1}^{m}\sum_{j=1}^{n}(B_{ij}-\bar{B})^{2}\right]}} \qquad (3.1)$$

A: the window around the pixel in the first image.
B: the window around the pixel in the second image.



If c:

= 1 then the windows in A and B are identical
= 0 then the windows in A and B are uncorrelated
= -1 then the windows in A and B are inverse (negative image)
> 0.7 the points have good correlation

2- Least squares differences.

The two windows A and B form two vectors V1 and V2 respectively.

$$c1 = \left(v(i_1\,, j_1), v(i_2, j_2)\right) = \left\| \frac{v_{2(i_2,j_2)}}{\|v_2(i_2,j_2)\|} - \frac{v_1(i_1,j_1)}{\|v_1(i_1,j_1)\|} \right\|^2 \qquad (3.2)$$

34	**56**	**134**	**10**	**103**	**105**	**120**	**107**
46	**67**	**67**	**87**	**94**	**100**	**110**	**109**
54	**65**	**66**	**54**	**75**	**87**	**91**	**93**
57	**60**	**63**	**54**	**6**	**76**	**80**	**80**
75	**69**	**75**	**51**	**54**	**56**	**67**	**73**
90	**73**	**85**	**65**	**58**	**57**	**63**	**87**
93	**80**	**76**	**48**	**57**	**75**	**86**	**89**
95	**76**	**94**	**10**	**102**	**101**	**103**	**101**

(i , j)

$$v(i,j) = \begin{pmatrix} 54 \\ 75 \\ 87 \\ 54 \\ 60 \\ 76 \\ 51 \\ 54 \\ 56 \end{pmatrix}$$

C = 0 , the two vectors are identical.
The pixels with minimum correlation is the matching pixel.

3- Centered least squares.

$$c\left((i_1, j_1), (i_2, j_2)\right) = \left\| \frac{v_2(i_2,j_2) - \mu_1}{\sigma_1} - \frac{v_1(i_1,j_1) - \mu_2}{\sigma_2} \right\| \qquad (3.3\ )$$

C=0 , the two vectors are identical.

4- Scalar product.

This defines the cosine of the angle between the two vectors , if the cosine is 1 , this means the angle is 0 and the two vectors are identical.

$$c_2\big((i_1, j_1), (i_2, j_2)\big) = \left\| \frac{v_1(i_1,j_1)v_2(i_2,j_2)}{\|v_1(i_1,j_1)\|\|v_2(i_2,j_2)\|} \right\|^2 \qquad (3.4)$$

C = 1 , the two vectors are identical.
C = 0, the vectors are are uncorrelated.
C > 0.7 , they have good correlation.

2) Feature based matching:

This method deals with features (points, lines, polygons), its complex. Features such as edges are extracted from the images, but its used to find the best match.

Advantages of this method:

1) Fast, since only a small subset of pixels are used.
2) Accurate, since features can be located with sub-pixel precision.
3) Are more robust with respect to radiometric and perspective distortion.

Disadvantage.

Sparse depth maps, matching only takes place where features occur. Intermediate matches must be interpolated.

Matching primitives

1) Zero crossing locations
direction of sign change, contour orientation.

2) Edges
end point coordinates, length, orientation, edge strength(contrast with respect to background),difference between grey levels on either side.

3) Regions
shape, size, relative geometry.
Suitable for smooth objects delineated by edges.

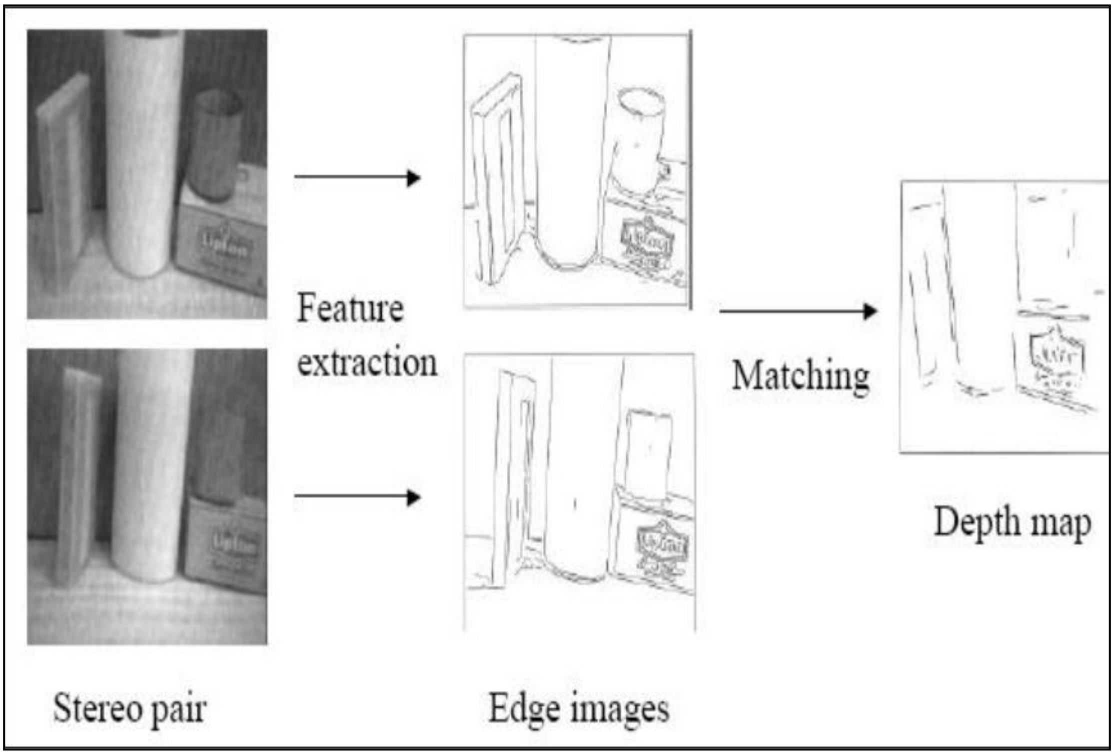


Figure (3-4): Feature Based matching

3.4.2 Definition of the search area

3.4.2.1 Image space.

Defining the search area on one of the two images depending the epipolar line where image coordinates in the left photo(x_1, y_1) are fixed. While the right image coordinates are changes along the epipolar line slowly, and each time find the ground X,Y,Z coordinates and the correlation coefficient. The point along the eppipolar line with best correlation coefficient value in the matching point(x_2, y_2). The X,Y,Z coordinates of point in the left photo(x_1, y_1) and the right photo (x_2, y_2) .

The estimated error in the elevation is.

$$\sigma_z = \frac{H}{B} * r * \sigma_{match} \qquad (3.5)$$

Where:
H: flying height .
B: air base .
r : The ground pixel size in meters.

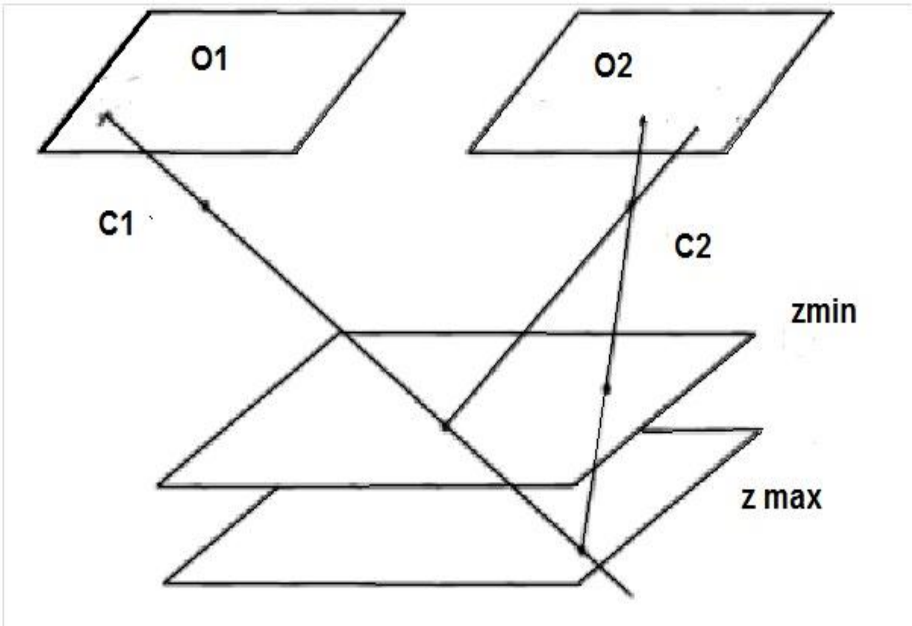


Figure (3-5):definition of search area using image space method.

3.4.2.2 Object space.

The search is done by moving the 3D object coordinates**.** In this method the XY ground coordinates of the point are fixed, z value change by small increment d_z .

$$d_z = \frac{H}{4B} * r_\circ \qquad (3.6)$$

Where:

H: flying height.
B: air base.
$r_\circ$: The ground pixel size in meters.

As the (z) changes we get using collinearity equation the values of the point coordinates in the left and right photo(x_1, y_1), (x_2, y_2) also the correlation coefficient is determined, (z) is still changing starting from the minimum to the maximum z-value. The point with the best correlation coefficient is the matching point.

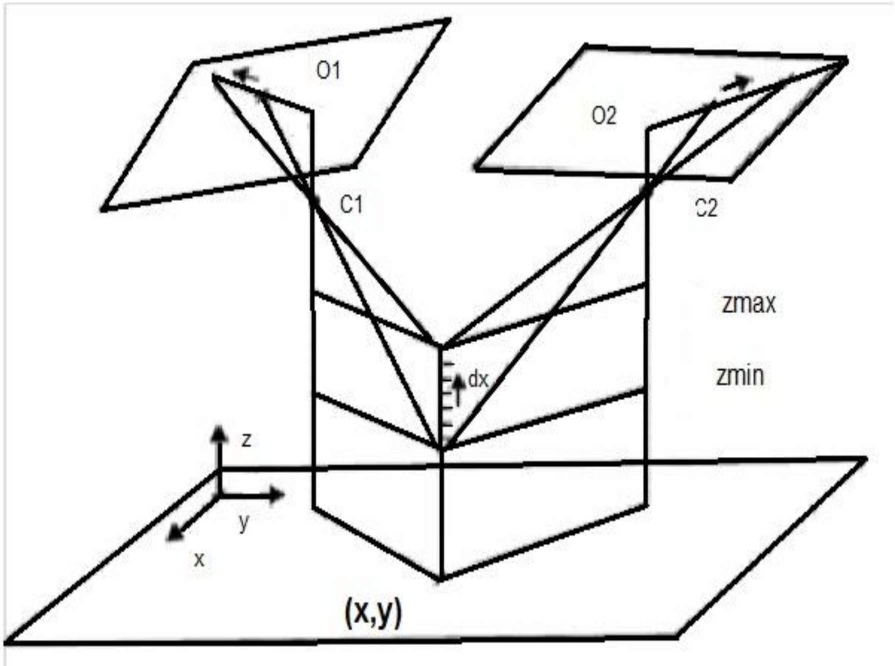


Figure (3-6) : definition of search area using object space method.

3.4.3 Manual DTM production

You can manually collect and edit DTM elevation points from a pair of overlapping digital aerial images that are displayed in stereo[13].

To collect DTM elevation points means to measure or to edit the Z value of a pont by clicking data (on the input device) where a specified point meets the ground. The software uses known X and Y values and established algorithms to calculate the Z value. See figure (3-7).

Figure (3-7): Manual DTM . [12]

3.5 Satellite DTM (remotely sensed data)

Generating DEMs from remotely sensed data can be cost effective and efficient. A variety of sensors and methodologies to generate such models are available and proven for mapping applications.Two primary methods if generating elevation data are: [14]

1) Stereogrammetry

which are techniques using airphotos (photogrammetry), VIR imagery, or radar data . Stereogrammetry involves the extraction of elevation information from stereo overlapping images, as in photogrammetric.

2) Radar interferometry

Interferometry involves the gathering of precise elevation data using successive passes (or dual antenna reception) of space borne or airborne. Subsequent images from nearly the same track are acquired and instead of examining the amplitude images, the phase information of the returned signals is compared. The phase images are co-registered, and the differences in phase value for each pixel is measured, and displayed as an interferogram. A computation of phase phase integration, and geometric rectification are performed to determine altitude values. [17]

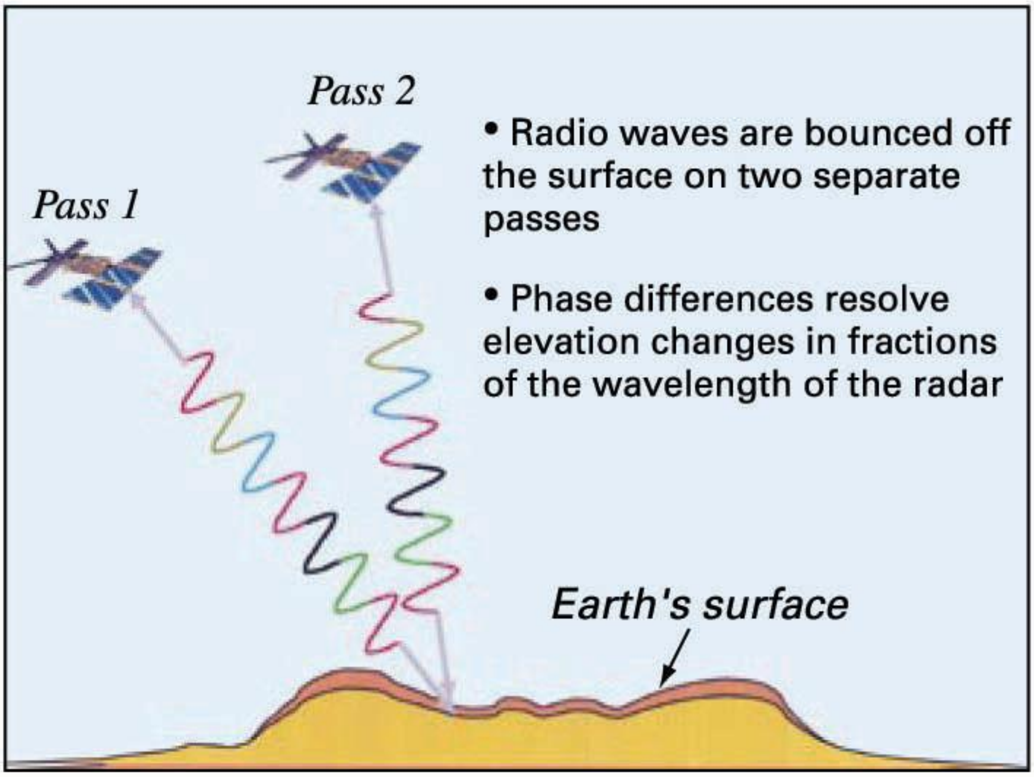
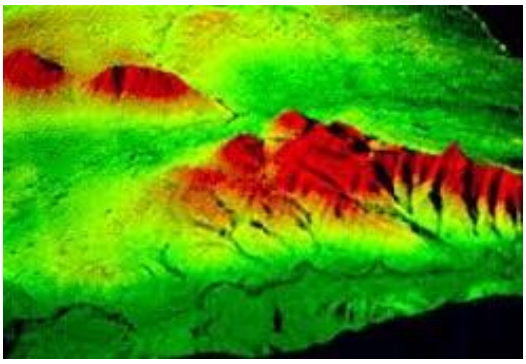


Figure (3-8) Radar interferometry.[17]

Primary applications of interferometry include high quality DEM generation, monitoring of surface deformations such as measurement of land subsidence due to natural processes, gas removal, or groundwater extraction, volcanic inflation p rior to eruption; relative earth movements caused by earthquakes, and hazard assessment and monitoring of natural landscape features and fabricated structures, such as dams. This type of data would be useful for insurance companies who could better measure damage due to natural disasters, and for hydrology-specialty companies and researchers interested in routine monitoring of ice jams for bridge safety, and changes in mass balance of glaciers or volcano growth prior to an eruption[17].

Figure (3-9): contour line from satellite imagery[17].

From elevation models, contour lines can be generated for topographic maps, slope and aspect models can be created for integration into (land cover) thematic classification datasets or used as a sole data source, or the model itself can be used to orthorectify remote sensing imagery and generate perspective views.



Figure(3-10) DTM from satellite imagery[17].

Data requirements

The basic data requirement for both stereogrammetric and interferometric techniques is that the target site has been imaged two times, with the sensor imaging positions separated to give two different viewing angles.

3.6 Global Satellite DTMs

Because of the improvement of remote sensing and space science instruments, it became possible to have global DTMs, so that, many international surveying agencies and associations cooperated to create these models, in this chapter it will be explained about two common global satellite models of them, which are SRTM, and GTOPO30.

3.6.1 SRTM Topography

The SRTM data sets result from a collaborative effort by the National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA - previously known as the National Imagery and Mapping Agency, or NIMA), as well as the participation of the German and Italian space agencies, to generate a near-global digital elevation model (DEM) of the Earth using radar interferometry. The SRTM instrument consisted of the Space borne Imaging Radar-C (SIR-C) hardware set modified with a Space Station-derived mast and additional antennae to form an interferometer with a 60 meter long baseline. Synthetic aperture radars are side-looking instruments and acquire data along continuous swaths. [15]

The SRTM swaths extended from about 30 degrees off-nadir to about 58 degrees off-nadir from an altitude of 233 km, and thus were about 225 km wide. During the data flight the instrument was operated at all times the orbiter was over land and about 1000 individual swaths were acquired over the ten days of mapping operations. Length of the acquired swaths range from a few hundred to several thousand km. Each individual data acquisition is referred to as a "data take."

SRTM was the primary payload on the STS-99 mission of the Space Shuttle Endeavour, which launched February 11, 2000 and flew for 11 days. Following several hours for instrument deployment, activation and checkout, systematic interferometric data were collected for 222.4 consecutive hours.

The instrument operated almost flawlessly and imaged 99.96% of the targeted landmass at least one time, 94.59% at least twice and about 50% at least three or more times. The goal was to image each terrain segment at least twice from different angles to fill in areas shadowed from the radar beam by terrain. This 'targeted landmass' consisted of all land between 56 degrees south and 60 degrees north latitude, which comprises almost exactly 80% of Earth’s total landmass.

Processing steps and versioning

In the first step raw SRTM radar echo data were processed using the SRTM Ground Data Processing System (GDPS) supercomputer system at the Jet Propulsion Laboratory. This processor transformed the radar echoes into strips of digital elevation data. These strips were then mosaicked into just less than 15,000 one degree by one degree cells and formatted according to the Digital Terrain Elevation Data (DTED) .

The data were processed on a continent-by-continent basis beginning with North America and proceeding through South America, Eurasia, Africa, Australia and Islands, with data from each continent undergoing a “block adjustment” to reduce residual errors.

In the next step NGA applied several post-processing procedures to these data including editing, spike and well removal, water body leveling and coastline definition. Following these "finishing" steps data were returned to NASA for distribution to the scientific and civil user communities as well as the public. These data were also reformatted into the SRTM format and are referred to as Version 2.

The figure below shows a portion of cell N34W119.hgt, demonstrating the difference between the edited and unedited data.

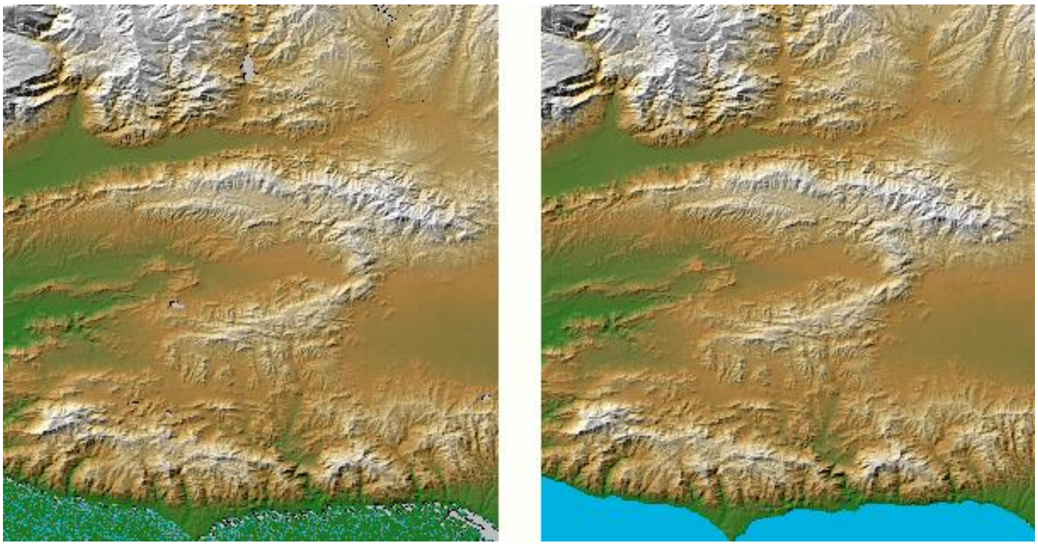


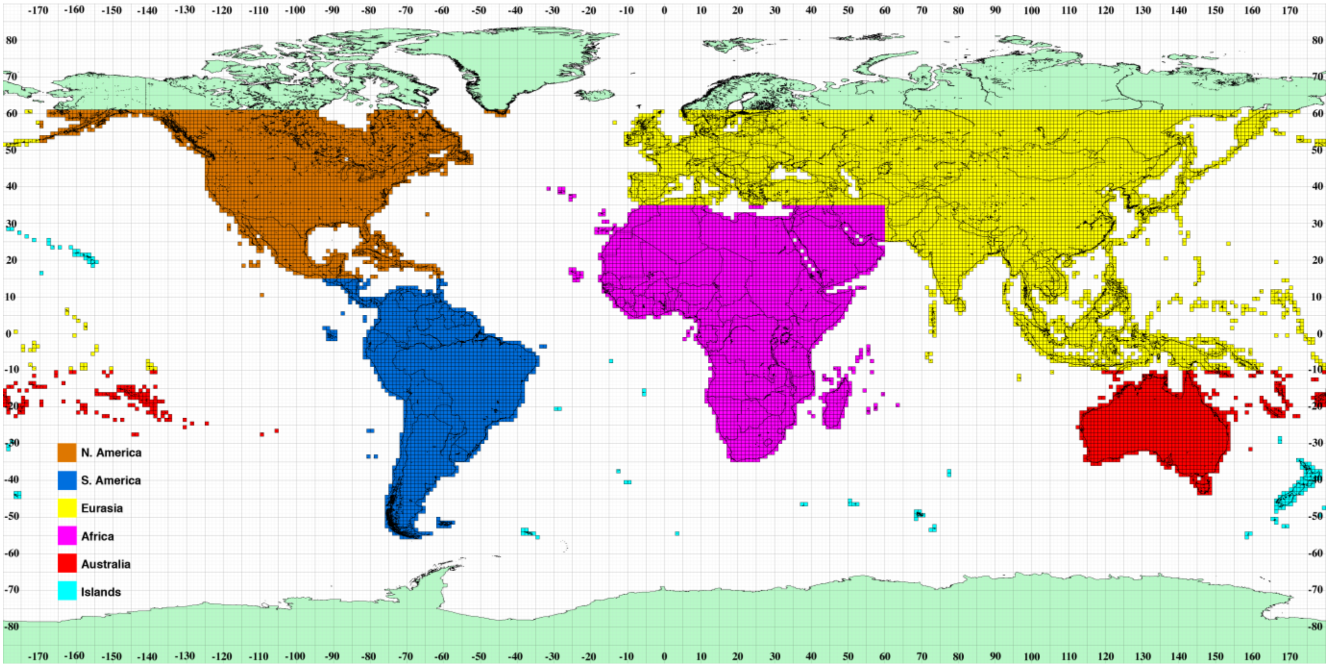
Figure (3-11) N34W119.hgt Unedited and edited data.

During the summer of 2009 the three arc-second sampled Version 2 data were replaced by Version 2.1, reflecting an improvement in the generation method. The editing for Version 2 had been applied by masking in the edited samples from the lower-resolution data publicly released by the NGA. This resulted in occasional artifacts, and in particular a very slight vertical “banding” in data beyond 50° latitude. For Version 2.1 the entire set was regenerated by averaging the full- resolution edited data which eliminated these artifacts, although most users will not notice the difference.

Organization

SRTM data are organized into individual rasterized cells, or tiles, each covering one degree by one degree in latitude and longitude. Sample spacing for individual data points is either 1 arc-second, 3 arc-seconds, or 30 arc-seconds, referred to as SRTM1, SRTM3 and SRTM30, respectively. Since one arc-second at the equator corresponds to roughly 30 meters in horizontal extent, the SRTM1 and SRTM3 are sometimes referred to as "30 meter" or "90 meter" data.

SRTM data were processed and delivered continent-by-continent and data for each continent are located in a separate directory on this server. The definitions of the continents are displayed in the figure below and at higher resolution in the file Continent_def.gif.



Figure(3-12) definition of content as displayed on SRTM data source[15] .

Elevation mosaics

Each SRTM data tile contains a mosaic of elevations generated by averaging all data takes that fall within that tile. Since the primary error source in synthetic aperture radar data is speckle, which has the characteristics of random noise, combining data through averaging reduces the error by the square root of the number of data takes used.

Data Formats

The names of individual data tiles refer to the longitude and latitude of the lower-left (southwest) corner of the . For example, the coordinates of the lower-left corner of tile N40W118 are 40 degrees north latitude and 118 degrees west longitude. To be more exact, these coordinates refer to the geometric center of the lower left sample, which in the case of SRTM3 data will be about 90 meters in extent.

SRTM Caveats

As with all digital geospatial data sets, users of SRTM must be aware of certain characteristics of the data set (resolution, accuracy, method of production and any resulting artifacts, etc.) in order to better judge its suitability for a specific application. A characteristic of SRTM that renders it unsuitable for one application may have no relevance as a limiting factor for its use in a different application.

3.6.2 GTOPO30 DTM

GTOPO30 is a global digital elevation model (DEM) resulting from a collaborative effort led by the staff at the U.S. Geological Survey's EROS Data Center in Sioux Falls, South Dakota.

Elevations in GTOPO30 are regularly spaced at 30-arc seconds (approximately 1 kilometer). GTOPO30 was developed to meet the needs of the geospatial data user community for regional and continental scale topographic data. This release represents the completion of global coverage of 30-arc second elevation data that have been available from the EROS Data Center beginning in 1993. Several areas have been updated and the entire global data set has been repackaged, so these data supersede the previously released continental data sets. [15]

Data Set Characteristics

GTOPO30 is a global data set covering the full extent of latitude from 90 degrees south to 90 degrees north, and the full extent of longitude from 180 degrees west to 180 degrees east. The horizontal grid spacing is 30-arc seconds (0.008333333333333 degrees), resulting in a DEM having dimensions of 21,600 rows and 43,200 columns. The horizontal coordinate system is decimal degrees of latitude and longitude referenced to WGS84.

The vertical units represent elevation in meters above mean sea level. The elevation values range from -407 to 8,752 meters. In the DEM, ocean areas have been masked as "no data" and have been assigned a value of -9999. Lowland coastal areas have an elevation of at least 1 meter, so in the event that a user reassigns the ocean value from -9999 to 0 the land boundary portrayal will be maintained. Due to the nature of the raster structure of the DEM, small islands in the ocean less than approximately 1 square kilometer will not be represented.

Data Format

To facilitate electronic distribution, GTOPO30 has been divided into 33 smaller pieces, or tiles. The area from 60 degrees south latitude to 90 degrees north latitude and from 180 degrees west longitude to 180 degrees east longitude is covered by 27 tiles, with each tile covering 50 degrees of latitude and 40 degrees of longitude. Antarctica (90 degrees south latitude to 60 degrees south latitude and 180 degrees west longitude to 180 degrees east longitude) is covered by 6 tiles, with each tile covering 30 degrees of latitude and 60 degrees of longitude. The tiles names refer to the longitude and latitude of the upper-left (northwest) corner of the tile. For example, the coordinates of the upper-left corner of tile E020N40 are 20 degrees east longitude and 40 degrees north latitude[16].

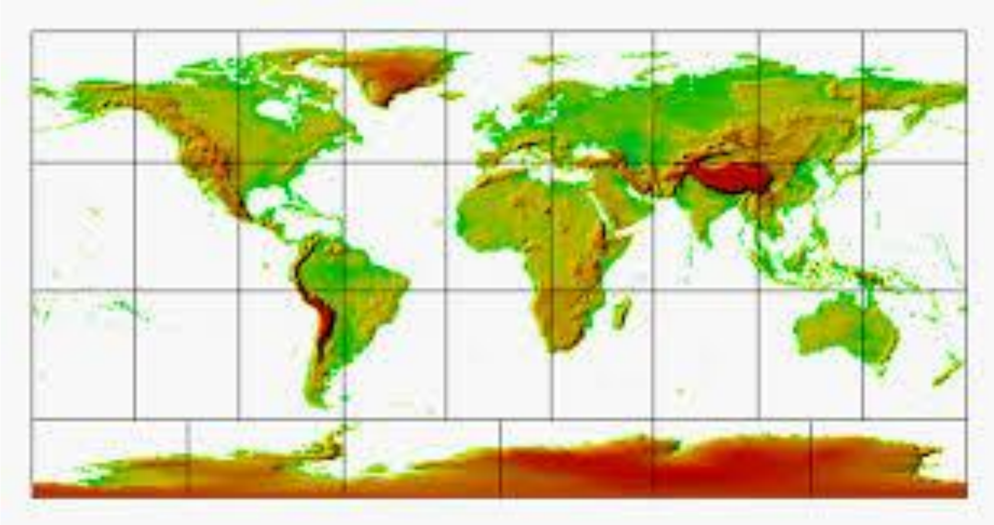


Figure (3-13) GTOPO30 DTM as displayed in its source

Data Sources

GTOPO30 is based on data derived from 8 sources of elevation information, including vector and raster data sets. The following table lists the percentage of the global land surface area derived from each source (a full description of each source is provided below)

Table 3.1 percentage of the global land surface area derived from each source

Source	% of global land area
Digital Terrain Elevation Data	50.0
Digital Chart of the World	29.9
USGS 1-degree DEM's	6.7
Army Map Service 1:1,000,000-scale maps	1.1
International Map of the World 1:1,000,000-scale maps	3.7
Peru 1:1,000,000-scale map	0.1
New Zealand DEM	0.2
Antarctic Digital Database	8.3

1) Digital Terrain Elevation Data

Digital Terrain Elevation Data (DTED) is a raster topographic data base with a horizontal grid spacing of 3-arc seconds (approximately 90 meters) produced by the National Imagery and Mapping Agency (NIMA). DTED was used as the source for most of Eurasia and large parts of Africa, South America, Mexico, Canada, and Central America.

2) Digital Chart of the World

Digital Chart of the World (DCW) is a vector cartographic data set based on the 1:1,000,000-scale Operational Navigation Chart (ONC) series, which is the largest scale base map source with global coverage. The DCW and the ONC series are products of NIMA.

The topographic information of interest for generating DEM's is contained in several DCW hypsography layers. The primary contour interval on the source ONC's is 1,000 feet (305 meters), and supplemental contours at an interval of 250 feet (76 meters) are shown in areas below 1,000 feet in elevation. In limited areas of higher elevation there supplemental contours at 500-foot (152-meter) intervals. The DCW drainage layers were also used as input to the DEM generation process; this information included stream networks, lake shorelines, lake elevations, and ocean coastlines. The DCW was used as the primary source for filling gaps in the DTED coverage, including all of Australia, most of Greenland, and large areas of Africa, South America, and Canada.

3) USGS Digital Elevation Models

USGS 1-degree DEM's with a horizontal grid spacing of 3-arc seconds (approximately 90 meters) were used as the source data for the continental United States, Alaska, and Hawaii. The topographic information content is similar to that of DTED. The "1-degree" designation refers to the unit of data distribution.

4) Army Map Service Maps

Paper maps at a scale of 1:1,000,000 produced by the Army Map Service (AMS). Contours (with intervals of 100, 150, 300, and 500 meters), spot heights, drainage lines , and coastlines for some islands of southeast Asia and some small areas in South America were delivered as digital vector cartographic data sets.

5) International Map of the World

Paper maps from the 1:1,000,000-scale International Map of the World (IMW) series were digitized by GIS to provide source data for the Amazon basin. The International Map of the World includes national maps produced to a United Nations specified standard for 1:1,000,000-scale mapping. The maps used for this project had a 100-meter contour interval.

6) Peru Map

Small areas of a 1:1,000,000-scale map from the Peruvian government were digitized to fill gaps in source data for South America. The map had a contour interval of 1,000 meters.

7) New Zealand DEM

Manaaki Whenua Landcare Research contributed a DEM with a 500-meter horizontal grid spacing for New Zealand. The DEM was derived from elevation information on 1:63,360-scale maps with a 100-foot (30-meter) contour interval.

8) Antarctic Digital Database

The Antarctic Digital Database (ADD) was produced under the auspices of the Scientific Committee on Antarctic Research. Digital contours and coastlines from the ADD were used as source material for Antarctica. The ADD vector data were compiled from maps ranging in scale from 1:200,000 to 1:5,000,000. The detail, density, and interval of the contours in the ADD vary widely, with the more detailed data near the coastline and very generalized data in the interior of the continent. Detailed metadata provided in the ADD identifies the map scale from which each contour line was extracted.

Data Processing

GTOPO30 was developed over a 3 year period during which continental and regional areas were produced individually. As such, processing techniques were developed and refined throughout the duration of the project. Although the techniques used for the various continental areas are very similar, there were some differences in approach due to varying source material.

Data processing was accomplished using commercially available geographic information system software, public domain image processing software, vector-to-raster gridding software, and utilities developed specifically for this project. To more efficiently handle the numerous input data sets and to standardize the proper sequence of processing steps, the production procedures were automated to a great extent by employing preset parameter values, scripted command files, and consistent naming schemes for input and output data files.

GTOPO30 Caveats

As with all digital geospatial data sets, users of GTOPO30 must be aware of certain characteristics of the data set (resolution, accuracy, methods of production and any resulting artifacts, etc.) in order to better judge its suitability for a specific application. A characteristic of GTOPO30 that renders it unsuitable for one application may have no relevance as a limiting factor for its use in a different application. Because only the end user can judge the applicability of the data set, it is the responsibility of the data producer to describe the characteristics of the data as fully as possible, so that an informed decision can be made by the user.

These types of DTMs will be used in our project to evaluate their accuracy in the study area, in addition to these global models, a local photogrammetric models will be used, and it will be obtained from the contour maps that will be obtained from the municipalities of some cities such as Hebron and Dura.

WORK AND ANALYSIS

4.1 Image Resampling

4.2 Interpolation

4.3 Resampling methods

4.4 Observation And Their Analysis

Work And Analysis

4.1 Image Resampling

Image resampling is the process of transforming a sampled image from one coordinate system to another. The two coordinate systems are related to each other by the mapping function of the spatial transformation. The inverse mapping function is applied to the output sampling grid, projecting it onto the input. The result is a resampling grid, specifying the locations at which the input is to be resampled. The input image is sampled at these points and the values are assigned to their respective output pixels[18].

The resampling grid does not generally coincide with the input sampling grid, taken to be the integer lattice. This is due to the fact that the range of the continuous mapping function is the set of real numbers. The solution requires a match between the domain of the input and the range of the mapping function. This is achieved by converting the discrete image samples into a continuous surface, i.e. by image reconstruction. Once the input is reconstructed, it can be resampled at any position[18].

Conceptually, image resampling is comprised of two stages: image reconstruction followed by sampling. Although resampling takes its name from the sampling stage, image reconstruction is the implicit component in this procedure. It is achieved through an interpolation procedure, and, in fact, the terms reconstruction and interpolation are often used interchangeably.

The image resampling process is depicted in Figure (4.1). A discrete input (squares) is shown passing through the image reconstruction module, yielding a continuous input signal (solid curve). Reconstruction is performed by convolving the discrete input signal with a continuous interpolating function. The reconstructed input is modulated (multiplied) with a resampling grid (dashed arrows). The resampling grid is the result of projecting the output grid onto the input through a spatial transformation. After the reconstructed signal is sampled by the resampling grid, the samples (circles) are assigned to the uniformly spaced output image.

4.2 Interpolation

Interpolation is defined as an informed estimate of the unknown using its surrounding values. Also it is a modelbased recovery of continuous data from discrete data within a known range of abscissa. The reason for this preference is to allow for a clearer distinction between interpolation and extrapolation. The former postulates the existence of a known range where the model applies, and asserts that the deterministically recovered continuous data is entirely described by the discrete data, while the latter authorizes the use of the model outside of the known range, with the implicit assumption that the model is "good" near data samples, and possibly less good elsewhere. the three most important hypothesis for interpolation are[20].

1) The underlying data is continuously defined.
2) Given data samples, it is possible to compute a data value of the underlying continuous function at any abscissa.
3) The evaluation of the underlying continuous function at the sampling points yields the same value as the data themselves.

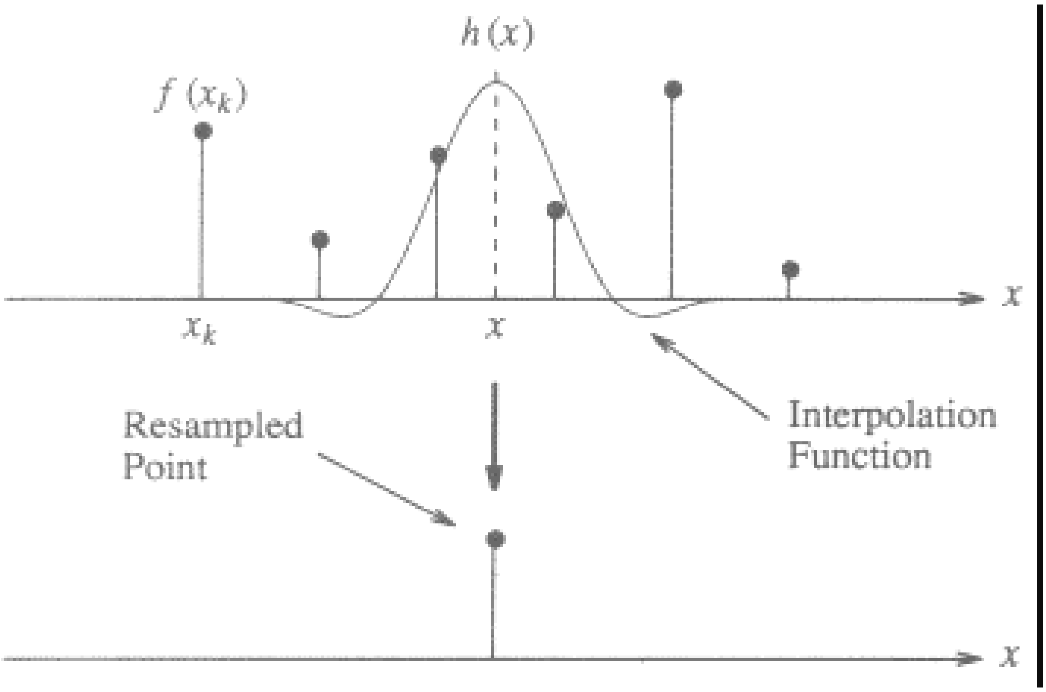


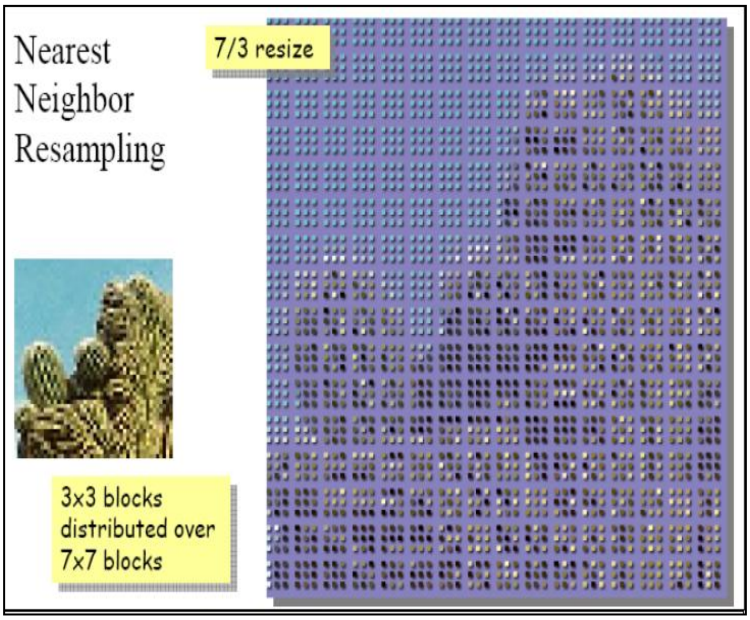
Figure (4-1) Interpolation of a single point.

4.3 Resampling methods

Generally there are three common interpolation methods used in image and DTM interpolation, which again lead to different results, these methods are: Nearest neighborhood, bi-linear, bi-cubic.

4.3.1 Nearest neighborhood

The simplest interpolation algorithm from a computational standpoint is the nearest neighbor algorithm, where each interpolated output pixel is assigned the value of the nearest sample point in the input image[4], see figure (4-4).



Figure(4-2) Nearest neighborhood

In figure (4-3), A pixel is superimposed at a fractional location (R 619.71, C 493.39) Rounding these values to the nearest integer yields 620 and 493 for the row and column indices, respectively. Thus, the resampled value is 56.

Various names are used to denote this simple kernel. They include the *box filter*, *sample-and-hold function*, and *Fourier window*.

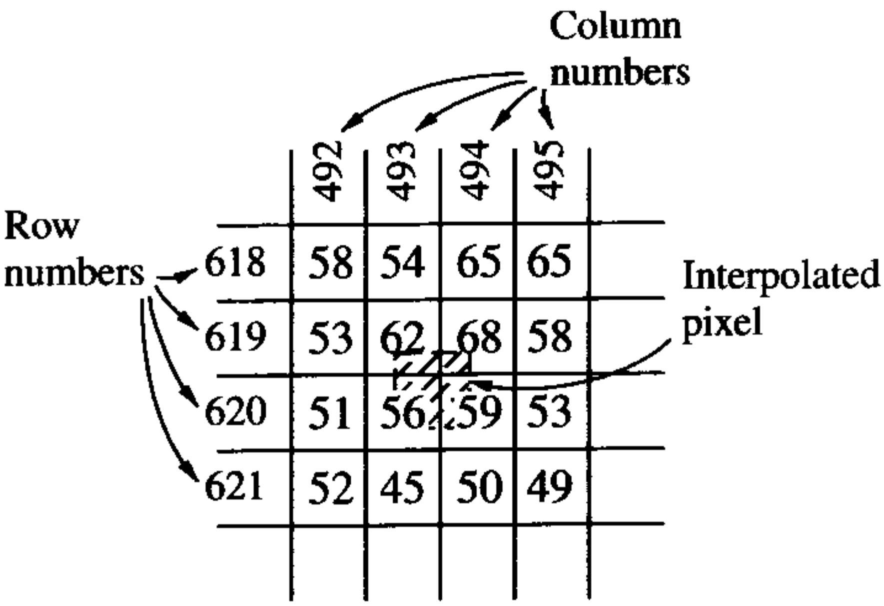


Figure (4-3) The resulting image after image registration

The nearest neighbor algorithm derives its primary use as a means for real-time magnification. For more sophisticated algorithms, this has only recently become realizable with the use of special-purpose hardware.

4.3.2 Bilinear

It is a linear interpolation in rows and columns, the interpolation range is the four surrounding 4 pixels. So it is the weighted mean of the closest 4 pixels [21].

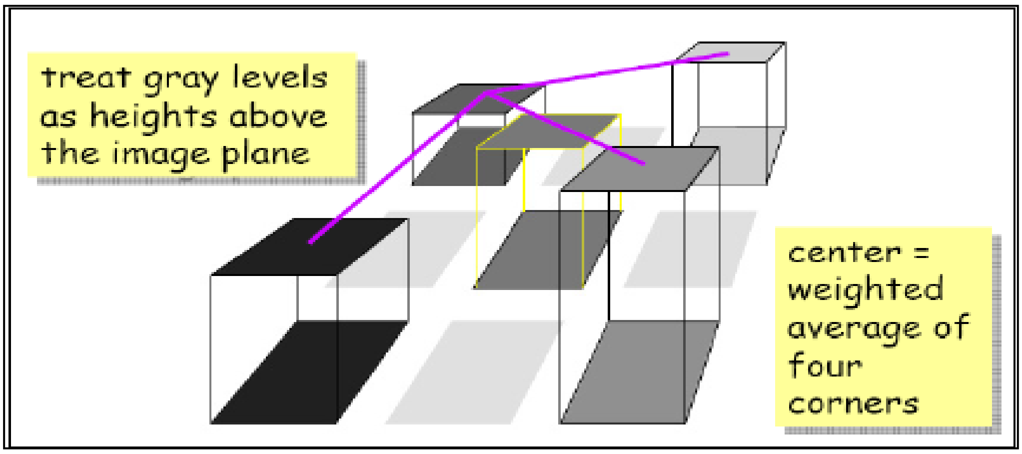


Figure (4-4) Bilinear.[4]

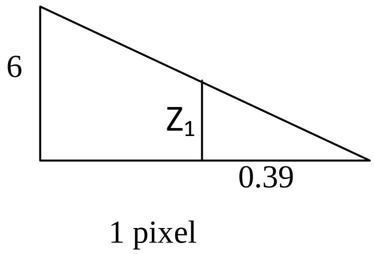
Example : Depending on the figure(4-3).

- linearly interpolated values DN1 and DN2 are computed along rows 619 and 620, respectively.

Xc = (619.71 , 493.39)

- Find its color by bilinear interpolation .

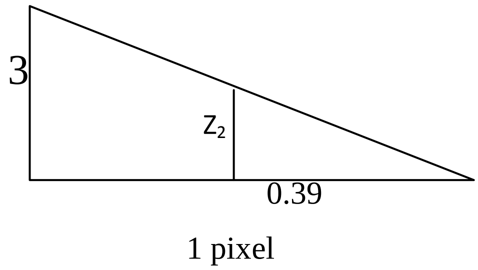
1) find the Z_1 .



$Z_1 = 0.39*6 = 2.34$ (4.1)

- Color = 62 + 2.34 = 64.34 (4.2)

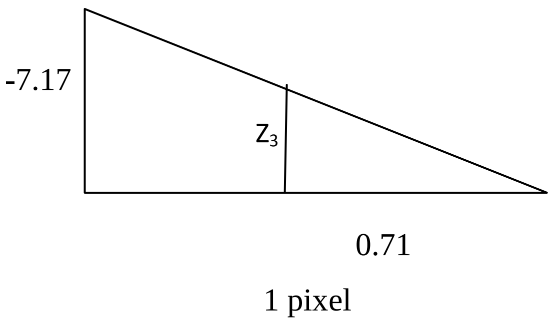
2) Find the Z_2.



$Z_2 = 0.39 * 3 = 1.17$ (4.3)

- Color = 56 + 1.17 = 57.17 (4.4)

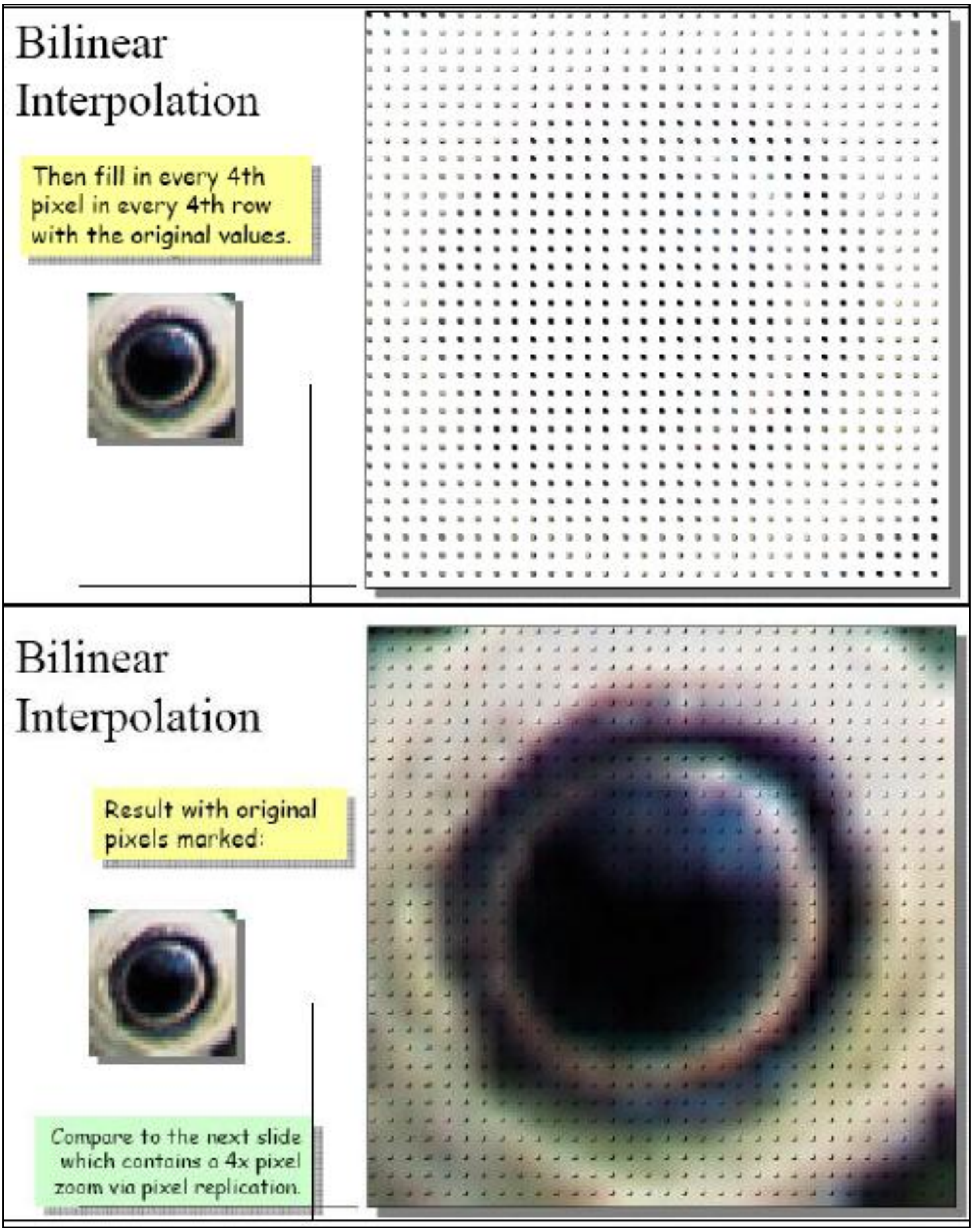
3) Interpolation about y- axis.



$Z_3 = -7.17 * 0.71 = -5.0907$ (4.5)

- Color = 64.34 – 5.09 = 59.25 (4.6)

- Finally, since DNs are generally integers, the value is rounded to 59

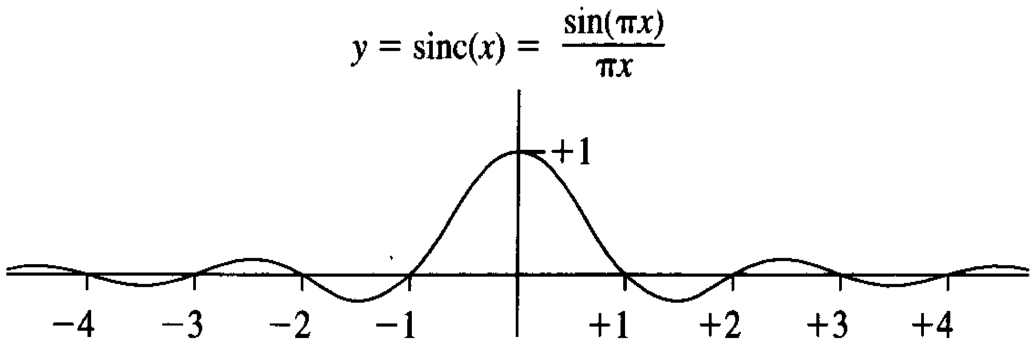


Figure(4-5) shows the zooming of 4 times using linear interpolation.

4.3.3 Bicubic

It is based on the fitting of two third degree polynomials to the region surrounding the point. The 16 nearest pixel values in the input image are used to estimate the value (r, c) on the output image[4]. The general form is shown in figure (4-6), and the results of resampling an image wihe bi-cubic method is explained in tables (4.1) , (4.2).

.



Figure(4-6) The bicubic ''sinc''function.

This function can be approximated to cubic functions as follows

.

$f_1(x) = (a + 2)x^3 – (a + 3)x + 1$, for $0 \le x \le 1$ (4.7)

$f_2(x) = ax^3 - 5ax^2 + 8ax – 4a$, for $1 \le x \le 2$ (4.8)

$f_3(x) = 0$, for $x \ge 2$ (4.9)

The constant a = free number define the weighting function at x = 1, best results when **a = - 0.5**.

The value of x = the absolute difference between the interpolated fractional pixel position and the column or row number.

1) The value of the weighting function for the rows is called r.

Table (4.1)

Element	Row	Distance x	Weighting function	Value
r_1	**618**	**1.71**	**$f_2(x)$**	**-0.02986**
r_2	**619**	**0.71**	**$f_1(x)$**	**0.27662**
r_3	**620**	**0.29**	**$f_1(x)$**	**0.82633**
r_4	**621**	**1.29**	**$f_2(x)$**	**-0.07309**

2) The value of the weighting function for the columns is called **c.**

Table (4.2)

Element	Column	Distance x	Weighting function	Value
c_1	**492**	**1.39**	**$f_2(x)$**	**-0.07256**
c_2	**493**	**0.39**	**$f_1(x)$**	**0.70873**
c_3	**494**	**0.61**	**$f_1(x)$**	**0.41022**
c_4	**495**	**1.61**	**$f_2(x)$**	**-0.04639**

4.4 Observation And Their Analysis

4.4 .1 Arithmetic mean

The observations are analyzed using the following statistical measure, arithmetic mean, error, RMSE, and in the next step and depending on the USGS96 standards, the best 95% observations will be used.

For a set of n observations, y1, y2, . . . , yn , the arithmetic mean is the average of the observations. Its value, y, is computed from the following equation[22].

$$\tilde{y} = \frac{\sum_{i=1}^{n} yi}{n} \qquad (4.10)$$

4.4 .2 True value

μ. The true value is a quantity's theoretically correct or exactvalue.

4.4 .3 Error, ε.

The error is the difference between any individual observed quantity and its true value.The true value is simply the population's arithmetic mean if all repeated observations have equal precision. Since the true value of an observed quantity is indeterminate, errors are also in determinate and are therefore only theoretical quantities[22].

$$\varepsilon i = yi - \mu \qquad (4.11)$$

Where
yi is the individual observation associated with εi and μ is the true value for that quantity.

4.4.4 Root Mean Square (RMS)

To simplify, we assume that we already have n samples of model errors _ calculated as (ei , i = 1,2, . . . ,n). The uncertainties brought in by observation errors or the method used to compare model and observations are not considered here. We also assume the error sample set _ is unbiased. The RMSE and the MAE are calculated for the data set as[22].

$$MAE = \frac{1}{n} \sum_{i=1}^{n} |ei| \qquad (4.12)$$

$$RMSE = \sqrt{\sum_{i=1}^{n} e_i^2} \qquad (4.13)$$

4. 4.5 (95) Percent Probable Error

Ninety-five percent probable error, or E95, is the bound within which, theoretically, 95% of the observation group's errors should fall. This error category is popular with surveyors for expressing precision and checking for outliers in data[22].

$$0.95 = P (|z| < t) = 2Nz (t) - 1 \qquad (4.14)$$

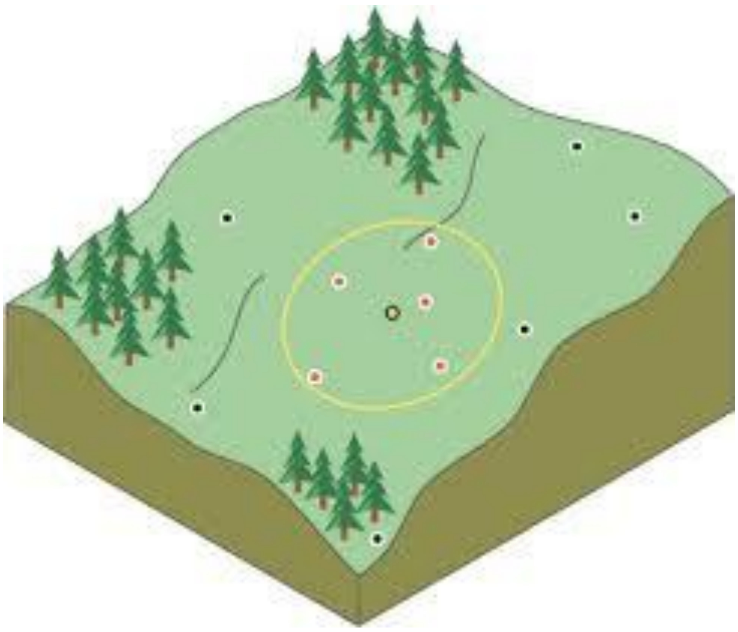
$$1.95 = 2Nz (t) \qquad (4.15)$$

$$0.975 = Nz (t) \qquad (4.16)$$

4.5 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.

This method assumes that the variable being mapped decreases in influence with distance from its sampled location. For example, when interpolating a surface of consumer purchasing power for a retail site analysis, the purchasing power of a more distant location will have less influence because people are more likely to shop closer to home



Figure(4-7). Inverse distance weighted

Capter 5 Results and analysis

5.1 Introduction

5.2 Testing Procedure

5.3 Results

5.1 Introduction

In this chapter, the results and data analysis will be presented. The data we worked on were collected from two main sources. Global DTMs (SRTM3, SRTM30 and GTOPO30), were gathered from open source topographic data website (www.webgis.com), and the Global Navigation Satellite System (GNSS) points were used to make the test on them according to the U.S. Geological Survey (USGS) standards, were gathered by GNSS surveying using RTK method to measure.

Local photogrammetric contour maps (Ad-dhahiriya contour map, Halhul contour map, Hebron contour map) were gathered from the municipalities of these cities, and processed to make test according to the USGS standards with respect to GNSS points were collected by GNSS and distributed to the coverage area of each map.

5.2 Testing Procedure

The National Standards for Spatial Data Accuracy (NSSDA) implements a statistical and testing methodology for estimating the positional accuracy of points on maps and in digital geospatial data with respect to georeferenced ground positions of higher accuracy.

The U.S. Department of the Interior, U.S. Geological Survey (USGS), National Mapping Division, maintains the National Standard for Spatial Data Accuracy (NSSDA) for the Federal Geographic Data Committee.

The NSSDA uses root-mean-square error (RMSE) to estimate positional accuracy. RMSE is the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points.

The accuracy is reported in ground distances at the 95% confidence level. Accuracy reported at the 95% confidence level means that 95% of the positions in the dataset will have an error with respect to true ground position that is equal to or smaller than the reported accuracy value. The reported accuracy value reflects all uncertainties, including those introduced by geodetic control coordinates, compilation, and final computation of ground coordinate values in the product.

According to the Spatial Data Transfer Standard (SDTS) (ANSI-NCITS, 1998), accuracy testing by an independent source of higher accuracy is the preferred test for positional accuracy.

Consequently, the NSSDA presents guidelines for accuracy testing by an independent source of higher accuracy. The independent source of higher accuracy shall the highest accuracy feasible and practicable to evaluate the accuracy of the dataset.

The data producer shall determine the geographic extent of testing. Horizontal accuracy shall be tested by comparing the planimetric coordinates of well-defined points in the dataset with coordinates of the same points from an independent source of higher accuracy. Vertical accuracy shall be tested by comparing the elevations in the dataset with elevations of the same points as determined from an independent source of higher accuracy.

Errors in recording or processing data, such as reversing signs or inconsistencies between the dataset and independent source of higher accuracy in coordinate reference system definition, must be corrected before computing the accuracy value.

Aminimum of 20 check points shall be tested, distributed to reflect the geographic area of interest and the distribution of error in the dataset.4 When 20 points are tested, the 95% confidence level allows one point to fail the threshold given in product specifications.

This methodology was applied on the global and local DTMs after they were processed as follows:

1- For global DTMs

1.1 we get 76 GPS points to start work as shown in table 5.1.
1.2 we applied the three resampling methods (Nearest neighbor, Bi-Linear, Bi-Cubic), on the GPS points by using QGIS software, to their elevation values from models.
1.3 We found the difference between GPS elevation and resampled elevation values for each point as: **(∆H = GPS elevation – Resampled elevation)**
1.4 We found the maximum and minimum values, mean and RMSE values for absolute values of ∆H.
1.5 At 95% probability, we removed the worst 4 values of ∆H for each method, then repeated step 1.4.
1.6 We drew the normal distribution for ∆H at 95% probability for each method.

2- For local DTMs

2.1 we got the contour maps, the converted them to grids using IDW method by using ArcGIS software, with changing the cell size 4 times with (5, 10, 20, 40) m for each time per each model.

2.2 Then we completed work as done for global DTMs with different number of GPS points for each model.

5.3 Results

This table shows the GNSS points that were used to test the Global DTMs in the West Bank of Palestine. The geographic coordinates (longitude, latitude) in degrees and the orthometric elevation in meters.

Table (5.1) GPS points used for check Global DTMs

Point No.	Longitude (°)	Latitude (°)	Elevation (Metre)	Point No.	Longitude (°)	Latitude (°)	Elevation (Metre)
1	35.265	32.262	668.47	39	35.001	31.526	728.56
2	35.248	32.246	590.77	40	35.988	31.427	666.83
3	35.266	32.290	602.58	41	35.092	31.379	794.5
4	35.250	32.291	548.76	42	35.203	31.561	822.82
5	35.279	32.215	601.14	43	35.159	31.946	751.87
6	35.194	32.252	370.95	44	35.251	31.932	846.04
7	35.203	32.225	568.71	45	35.175	31.923	746.75
8	35.222	32.541	109.21	46	35.211	31.911	871.9
9	35.314	32.487	124.05	47	35.229	31.967	713.61
10	35.342	32.472	158.69	48	35.191	31.889	848.58
11	35.319	32.460	193.25	49	35.200	31.864	810.51
12	35.325	32.420	371.41	50	35.299	32.013	792.24
13	35.317	32.428	352.27	51	35.113	32.056	477.98
14	35.273	32.448	305.92	52	35.168	31.986	661.42
15	35.275	32.443	274.43	53	35.076	31.951	424.24
16	35.195	32.415	380.86	54	35.075	31.942	397.77
17	35.241	32.461	290.79	55	35.383	32.317	355.19
18	35.374	32.495	310.66	56	35.370	32.343	506.69
19	35.195	32.517	229.44	57	35.024	32.296	86.02
20	35.256	32.470	243.51	58	35.040	32.304	140.23
21	35.197	32.406	359.14	59	35.032	32.326	86.32
22	35.171	32.354	404.3	60	35.112	32.301	319.4
23	35.113	31.419	794.37	61	35.182	32.222	480.54
24	35.076	31.440	810.53	62	35.111	32.199	412.03
25	35.064	31.449	773.88	63	35.057	32.128	234.45
26	35.070	31.455	773.99	64	35.027	32.142	203.72
27	35.176	31.527	942.723	65	35.002	32.158	173.16
28	34.986	31.567	506.604	66	34.972	32.180	73.49
29	35.023	31.570	614.534	67	34.989	32.193	116.52
30	35.074	31.649	638.451	68	35.037	32.179	252.29
31	35.064	31.652	589.901	69	35.065	32.182	275.98
32	35.110	31.500	901.37	70	35.049	32.191	255.72
33	35.057	31.460	738.18	71	35.068	32.192	316.44
34	34.920	31.411	641.04	72	35.031	32.229	156.14
35	35.075	31.618	848.41	73	35.097	32.238	389.17
36	35.022	31.588	566.5	74	35.093	32.249	318.72
37	35.060	31.558	874.83	75	35.095	32.324	323.62
38	35.058	31.505	913.19	76	35.057	32.385	101.49

5.3.1 Global DTMs (properties and analysis) :

5.3.1.1 SRTM 3

SRTM is an international project spearheaded by the National Geospatial-Intelligence Agency (NGA), NASA, the Italian Space Agency (ASI) and the German Aerospace Center (DLR). This data was collected during the Shuttle Radar Topography Mission (SRTM) and contains global coverage from 56 degrees south latitude to 60 degrees north latitude in 1 by 1 degree blocks with an approximate resolution of 90 by 90 meters.

The coordinates system of this model is The World Geodetic System 1984 (GSC_WGS84).

Resampled elevations are introduced in table (5.2), which were interpolated by the three methods of resampling, these methods are (Nearest Neighbor, Bi-Linear and Bi-Cubic), and ΔH for each method.

Table (5.2) shows resampled elevations and ΔH for each method of resampling.

Table (5.2) resampled elevations and ΔH for each method of resampling(STRM 3).

Point No.	Nearest Neighbor (m)	Δ(H1) (m)	Bi-Linear (m)	Δ(H2) (m)	Bi-Cubic (m)	Δ(H3) (m)	Point No.	Nearest Neighbor (m)	Δ(H1) (m)	Bi-Linear (m)	Δ(H2) (m)	Bi-Cubic (m)	Δ(H3) (m)
1	664	4.470	662.841	5.629	664.571	3.899	39	724	4.560	721.954	6.606	723.759	4.801
2	577	13.770	575.984	14.786	579.870	10.900	40	729	-62.170	728.991	-62.161	728.814	-61.984
3	598	4.580	594.931	7.649	596.599	5.981	41	791	3.500	790.891	3.609	791.751	2.749
4	523	25.760	533.285	15.475	538.055	10.705	42	819	3.820	816.623	6.197	817.953	4.867
5	606	-4.860	590.531	10.609	590.917	10.223	43	747	4.870	746.859	5.011	746.803	5.067
6	364	6.950	363.048	7.902	365.399	5.551	44	873	-26.960	872.200	-26.160	871.442	-25.402
7	562	6.710	558.308	10.402	560.433	8.277	45	743	3.750	741.948	4.802	742.737	4.013
8	106	3.210	106.000	3.210	106.539	2.671	46	882	-10.100	881.022	-9.122	881.376	-9.476
9	115	9.050	117.665	6.385	118.095	5.955	47	708	5.610	703.398	10.212	704.465	9.145
10	158	0.690	156.197	2.493	157.157	1.533	48	842	6.580	839.565	9.015	839.944	8.636
11	187	6.250	187.546	5.704	188.000	5.250	49	795	15.510	793.404	17.106	793.399	17.111
12	363	8.410	364.697	6.713	365.792	5.618	50	787	5.240	786.664	5.576	787.687	4.553
13	346	6.270	345.299	6.971	345.757	6.513	51	463	14.980	458.884	19.096	460.937	17.043
14	300	5.920	299.132	6.788	299.484	6.436	52	650	11.420	647.925	13.495	649.063	12.357
15	271	3.430	270.401	4.029	271.151	3.279	53	420	4.240	420.436	3.804	421.555	2.685
16	379	1.860	376.661	4.199	378.368	2.492	54	391	6.770	390.727	7.043	391.948	5.822
17	284	6.790	281.766	9.024	284.581	6.209	55	351	4.190	352.610	2.580	352.672	2.518
18	301	9.660	301.488	9.172	302.065	8.595	56	503	3.690	502.560	4.130	503.087	3.603

19	228	1.440	227.141	2.299	227.405	2.035	57	83	3.020	81.954	4.066	83.773	2.247
20	237	6.510	238.065	5.445	239.402	4.108	58	139	1.230	138.692	1.538	139.526	0.704
21	353	6.140	352.089	7.051	353.947	5.193	59	83	3.320	82.808	3.512	83.390	2.930
22	383	21.300	386.670	17.630	389.970	14.330	60	317	2.400	314.534	4.866	316.370	3.030
23	788	6.370	787.447	6.923	789.062	5.308	61	476	4.540	475.949	4.591	477.725	2.815
24	806	4.530	804.575	5.955	805.775	4.755	62	412	0.030	411.395	0.635	411.969	0.061
25	769	4.880	766.244	7.636	768.460	5.420	63	225	9.450	226.106	8.344	227.225	7.225
26	765	8.990	764.134	9.856	766.441	7.549	64	199	4.720	199.318	4.402	201.237	2.483
27	942	0.723	940.265	2.458	941.260	1.463	65	172	1.160	171.221	1.939	172.232	0.928
28	503	3.604	499.646	6.958	502.264	4.340	66	76	-2.510	73.917	-0.427	74.202	-0.712
29	608	6.534	606.248	8.286	607.781	6.753	67	116	0.520	112.993	3.527	114.000	2.520
30	632	6.451	630.675	7.776	634.872	3.579	68	256	-3.710	254.613	-2.323	254.960	-2.670
31	580	9.901	578.601	11.300	581.813	8.088	69	272	3.980	271.054	4.926	272.085	3.895
32	896	5.370	895.318	6.052	896.710	4.660	70	256	-0.280	255.007	0.713	255.567	0.153
33	738	0.180	737.735	0.445	738.317	-0.137	71	312	4.440	311.602	4.838	312.132	4.308
34	641	0.040	641.013	0.027	641.857	-0.817	72	148	8.140	149.071	7.069	150.956	5.184
35	844	4.410	844.434	3.976	847.442	0.968	73	389	0.170	387.077	2.093	388.303	0.867
36	563	3.500	563.419	3.081	564.841	1.659	74	315	3.720	312.093	6.627	313.421	5.299
37	869	5.830	867.800	7.030	870.032	4.798	75	314	9.620	311.582	12.038	313.403	10.217
38	906	7.190	904.583	8.607	905.902	7.288	76	100	1.490	98.959	2.531	99.633	1.857

For each **ΔH** we found the statistical parameters includes (maximum value, minimum value, mean and RMSE) and table (5.3) shows that results.

Table (5.3) Statistical Results for SRTM3 DTM

	ΔH1	ΔH2	ΔH3
Maximum	25.760	19.096	17.110
Minimum	-62.170	-62.162	-61.984
Mean	6.697	7.403	6.122
RMSE	8.145	7.805	7.733

After that we worked on 95% confidence level and table (5.4) shows the statistical results after removing the worst 5% observations.

Table (5.4) Statistical Results for SRTM3 DTM at 95% probability

	ΔH1	ΔH2	ΔH3
Maximum	15.510	17.106	14.330
Minimum	-10.100	-9.122	-9.476
Mean	5.177	6.078	4.77
RMSE	3.356	3.558	3.077

5.3.1.2 SRTM 30

One of SRTM models with resolution of 30 seconds (approximately 1 km by 1 km). And the coordinates system for this model is (GCS_WGS1984).

Table (5.5) shows resampled elevations and ΔH for each method of resampling.

Table (5.8) shows resampled elevations and ΔH for each method of resampling(GTOPO 30).

Point No.	Nearest Neighbor (m)	Δ(H1) (m)	Bi-Llinear (m)	Δ(H2) (m)	Bi-Cubic (m)	Δ(H3) (m)	Point No.	Nearest Neighbor (m)	Δ(H1) (m)	Bi-Llinear (m)	Δ(H2) (m)	Bi-Cubic (m)	Δ(H3) (m)
1	670.000	-1.530	667.188	1.282	684.870	-16.400	39	601.000	127.560	659.430	69.130	668.394	60.166
2	494.000	96.770	511.848	78.922	507.335	83.435	40	750.000	-83.170	737.426	-70.596	734.932	-68.102
3	472.000	130.580	540.794	61.786	516.252	86.328	41	803.000	-8.500	791.319	3.181	796.055	-1.555
4	592.000	-43.240	525.266	23.494	525.161	23.599	42	677.000	145.820	689.819	133.001	674.484	148.336
5	513.000	88.140	658.375	-57.235	634.079	-32.939	43	755.000	-3.130	761.822	-9.952	770.583	-18.713
6	413.000	-42.050	363.422	7.528	351.073	19.877	44	915.000	-68.960	915.177	-69.137	926.611	-80.571
7	382.000	186.710	423.677	145.033	417.384	151.326	45	802.000	-55.250	730.597	16.153	750.917	-4.167
8	98.000	11.210	108.298	0.912	106.379	2.831	46	899.000	-27.100	884.143	-12.243	894.391	-22.491
9	103.000	21.050	104.643	19.407	100.463	23.587	47	784.000	-70.390	704.513	9.097	702.471	11.139
10	169.000	-10.310	160.816	-2.126	159.637	-0.947	48	862.000	-13.420	864.233	-15.653	872.669	-24.089
11	131.000	62.250	181.421	11.829	182.289	10.961	49	809.000	1.510	807.939	2.571	820.317	-9.807
12	363.000	8.410	339.673	31.737	335.559	35.851	50	809.000	-16.760	790.448	1.792	800.052	-7.812
13	271.000	81.270	307.718	44.552	306.561	45.709	51	461.000	16.980	405.292	72.688	408.692	69.288
14	310.000	-4.080	314.218	-8.298	335.187	-29.267	52	687.000	-25.580	642.689	18.731	643.731	17.689
15	310.000	-35.570	284.117	-9.687	289.804	-15.374	53	323.000	101.240	359.451	64.789	352.877	71.363
16	382.000	-1.140	326.877	53.983	336.399	44.461	54	439.000	-41.230	356.588	41.182	351.696	46.074
17	224.000	66.790	254.744	36.046	242.724	48.066	55	374.000	-18.810	387.244	-32.054	386.676	-31.486
18	307.000	3.660	285.191	25.469	289.876	20.784	56	514.000	-7.310	511.063	-4.373	527.595	-20.905

19	248.000	-18.560	240.667	-11.227	248.173	-18.733	57	102.000	-15.980	87.634	-1.614	85.931	0.089
20	249.000	-5.490	228.207	15.303	233.929	9.581	58	80.000	60.230	87.122	53.108	81.139	59.091
21	280.000	79.140	305.256	53.884	305.527	53.613	59	111.000	-24.680	101.866	-15.546	98.390	-12.070
22	315.000	89.300	318.063	86.237	317.702	86.598	60	318.000	1.400	312.883	6.517	323.153	-3.753
23	775.000	19.370	776.226	18.144	779.660	14.710	61	483.000	-2.460	433.620	46.920	426.172	54.368
24	720.000	90.530	755.802	54.728	758.753	51.777	62	355.000	57.030	397.998	14.032	413.719	-1.689
25	762.000	11.880	717.343	56.537	721.337	52.543	63	252.000	-17.550	258.463	-24.013	255.612	-21.162
26	678.000	95.990	676.362	97.628	672.175	101.815	64	146.000	57.720	123.214	80.506	111.887	91.833
27	942.000	0.723	910.906	31.817	926.651	16.072	65	177.000	-3.840	175.195	-2.035	182.264	-9.104
28	405.000	101.604	454.040	52.564	457.801	48.803	66	50.000	23.490	66.316	7.174	65.546	7.944
29	608.000	6.534	631.025	-16.491	644.410	-29.876	67	96.000	20.520	107.769	8.751	108.165	8.355
30	659.000	-20.549	634.468	3.983	642.788	-4.337	68	203.000	49.290	204.838	47.452	204.188	48.102
31	593.000	-3.099	561.995	27.906	565.572	24.329	69	308.000	-32.020	312.611	-36.631	318.114	-42.134
32	895.000	6.370	852.589	48.781	855.449	45.921	70	266.000	-10.280	242.201	13.519	245.209	10.511
33	681.000	57.180	670.072	68.108	662.292	75.888	71	324.000	-7.560	277.764	38.676	276.262	40.178
34	570.000	71.040	585.161	55.879	585.802	55.238	72	110.000	46.140	127.246	28.894	121.654	34.486
35	838.000	10.410	764.841	83.569	776.956	71.454	73	401.000	-11.830	363.649	25.521	378.912	10.258
36	564.000	2.500	558.340	8.160	562.272	4.228	74	340.000	-21.280	267.927	50.793	259.169	59.551
37	784.000	90.830	840.512	34.318	843.878	30.952	75	324.000	-0.380	272.594	51.026	278.274	45.346
38	902.000	11.190	881.901	31.289	882.849	30.341	76	60.000	41.490	77.190	24.300	78.696	22.794

We found the statistical parameters for ΔH and results are introduced in table (5.6)

Table (5.6) Statistical Results for SRTM30 DTM

	Δ(H1)	Δ(H2)	Δ(H3)
Maximum	105.620	105.461	1i04.234
Minimum	-69.170	-70.788	-70.530
Mean	35.477	37.264	36.621
RMSE	23.746	21.481	21.110

After that we worked at 95% probability, and the results are introduced in table (5.7):

Table (5.7) Statistical Results for SRTM30 DTM at 95% probability

	Δ(H1)	Δ(H2)	Δ(H3)
Maximum	82.980	73.552	69.890
Minimum	-69.170	-70.788	-70.530
Mean	32.210	34.355	33.817
RMSE	19.734	17.886	17.692

5.3.1.3 GTOPO30

GTOPO30 is a digital elevation model for the world, developed by USGS. It has a 30-arc second resolution (approximately 1 km by 1 km), and is split into 33 tiles stored in the USGS DEM file format.

Table (5.8) shows resampled elevations and ΔH for each method

Table (5.5) resampled elevations and ΔH for each method of resampling(STRM 30).

Point No.	Nearest Neighbor (m)	Δ(H1) (m)	Bi-Linear (m)	Δ(H2) (m)	Bi-Cubic (m)	Δ(H3) (m)	Point No.	Nearest Neighbor (m)	Δ(H1) (m)	Bi-Linear (m)	Δ(H2) (m)	Bi-Cubic (m)	Δ(H3) (m)
1	628.000	40.470	624.598	43.872	630.385	38.085	39	677.000	51.560	664.937	63.623	667.130	61.430
2	551.000	39.770	566.350	24.420	564.099	26.671	40	736.000	-69.170	737.618	-70.788	737.360	-70.530
3	523.000	79.580	558.423	44.157	551.422	51.158	41	784.000	10.500	771.969	22.531	772.937	21.563
4	536.000	12.760	520.752	28.008	515.435	33.325	42	759.000	63.820	764.259	58.561	768.268	54.552
5	570.000	31.140	627.029	-25.889	611.758	-10.618	43	729.000	22.870	720.297	31.573	726.677	25.193
6	367.000	3.950	352.536	18.414	343.740	27.210	44	871.000	-24.960	870.647	-24.607	877.935	-31.895
7	482.000	86.710	492.239	76.471	498.820	69.890	45	723.000	23.750	686.296	60.454	688.900	57.850
8	109.000	0.210	100.895	8.315	101.911	7.299	46	866.000	5.900	861.815	10.085	865.908	5.992
9	112.000	12.050	112.185	11.865	111.319	12.731	47	721.000	-7.390	690.889	22.721	686.751	26.859
10	152.000	6.690	146.163	12.527	145.732	12.958	48	793.000	55.580	804.802	43.778	806.164	42.416
11	152.000	41.250	176.945	16.305	176.114	17.136	49	761.000	49.510	770.145	40.365	773.584	36.926
12	355.000	16.410	347.139	24.271	346.625	24.785	50	748.000	44.240	744.416	47.824	739.776	52.464
13	310.000	42.270	315.178	37.092	315.915	36.355	51	395.000	82.980	372.519	105.461	373.746	104.234
14	273.000	32.920	275.125	30.795	283.019	22.901	52	638.000	23.420	632.288	29.132	631.100	30.320
15	273.000	1.430	261.127	13.303	260.947	13.483	53	373.000	51.240	375.790	48.450	373.984	50.256
16	338.000	42.860	311.712	69.148	316.784	64.076	54	404.000	-6.230	361.402	36.368	360.837	36.933
17	281.000	9.790	259.564	31.226	256.467	34.323	55	354.000	1.190	359.721	-4.531	355.202	-0.012
18	265.000	45.660	262.432	48.228	264.230	46.430	56	473.000	33.690	464.416	42.274	473.894	32.796
19	189.000	40.440	197.908	31.532	197.270	32.170	57	71.000	15.020	69.467	16.553	69.303	16.717

20	203.000	40.510	203.859	39.651	206.206	37.304	58	102.000	38.230	106.774	33.456	107.436	32.794
21	317.000	42.140	322.780	36.360	324.445	34.695	59	80.000	6.320	84.402	1.918	81.886	4.434
22	346.000	58.300	345.699	58.601	346.316	57.984	60	230.000	89.400	245.848	73.552	247.764	71.636
23	762.000	32.370	765.937	28.433	765.955	28.415	61	421.000	59.540	418.959	61.581	414.264	66.276
24	763.000	47.530	767.999	42.531	773.163	37.367	62	354.000	58.030	376.315	35.715	381.627	30.403
25	746.000	27.880	729.128	44.752	729.479	44.401	63	220.000	14.450	233.220	1.230	230.758	3.692
26	734.000	39.990	730.660	43.330	729.290	44.700	64	187.000	16.720	160.015	43.705	157.907	45.813
27	899.000	43.723	897.319	45.404	905.820	36.903	65	156.000	17.160	151.829	21.331	155.129	18.031
28	452.000	54.604	467.186	39.418	467.598	39.006	66	64.000	9.490	70.167	3.323	69.977	3.513
29	547.000	67.534	571.773	42.761	570.014	44.520	67	90.000	26.520	100.225	16.295	100.286	16.234
30	599.000	39.451	607.076	31.375	600.913	37.538	68	243.000	9.290	240.882	11.408	240.991	11.299
31	535.000	54.901	540.760	49.141	538.446	51.455	69	273.000	2.980	276.674	-0.694	279.360	-3.380
32	850.000	51.370	849.366	52.004	850.846	50.524	70	222.000	33.720	233.785	21.935	234.214	21.506
33	722.000	16.180	710.682	27.498	706.604	31.576	71	286.000	30.440	261.393	55.047	261.109	55.331
34	619.000	22.040	613.593	27.447	617.307	23.733	72	128.000	28.140	131.966	24.174	129.883	26.257
35	753.000	95.410	764.237	84.173	766.917	81.493	73	346.000	43.170	327.455	61.715	333.907	55.263
36	537.000	29.500	542.408	24.092	542.775	23.725	74	292.000	26.720	255.535	63.185	250.678	68.042
37	840.000	34.830	832.942	41.888	835.144	39.686	75	218.000	105.620	231.232	92.388	232.643	90.977
38	881.000	32.190	862.609	50.581	864.145	49.045	76	81.000	20.490	77.031	24.459	77.785	23.705

We found the statistical parameters for ΔH and results are introduced in table (5.9), then we worked at probability of 95% and results are introduced in table (5.10).

Table (5.9) Statistical Results for GTOPO30 DTM

	Δ(H1)	Δ(H2)	Δ(H3)
Maximum	186.71	145.033	151.326
Minimum	-83.17	-83.17	-80.571
Mean	39.802	35.516	37.041
RMSE	40.015	30.235	31.478

Table (5.10) Statistical Results for GTOPO30 DTM at 95% probability

	Δ(H1)	Δ(H2)	Δ(H3)
Maximum	101.604	83.569	86.598
Minimum	-83.17	-70.5963	-80.5714
Mean	33.809	31.074	32.247
RMSE	31.256	23.607	23.865

5.3.2 Local DTMs (properties and analysis) :

5.3.2.1 Ad-Dhahiriya Contour Map

We got the contour map from Dahiriya Municipality with contour interval of (2.5 m), then we created DTM using ArcGIS (IDW method) with different cell size. The coordinates system for this model is (Palestine_1923_Palestine_Grid). Table(5.11) showing the GNSS points used to evaluate the accuracy of these models.

Table(5.11) GNSS points which were used to evaluate Ad-dhahiriya DTM accuracy

Point No.	Easting (m)	Northing (m)	Elevation (m)	Point No.	Easting (m)	Northing (m)	Elevation (m)
1	149100.417	93784.460	671.263	17	145721.584	90652.280	579.663
2	148654.602	93134.328	651.079	18	146754.449	90770.921	618.388
3	148654.600	93134.360	651.084	19	147288.319	90888.796	645.539
4	148167.573	93263.811	654.851	20	147511.881	90928.067	648.185
5	148167.597	93263.809	654.793	21	146890.621	90316.117	605.756
6	148166.666	93261.893	654.315	22	146608.178	89843.452	589.838
7	147665.459	92916.319	638.135	23	147802.944	90323.833	634.152
8	147659.412	92922.953	639.879	24	147794.974	89955.472	639.858
9	147660.039	92922.949	639.662	25	147727.910	90976.919	637.127
10	147330.902	92418.693	640.198	26	148534.816	91000.055	622.943
11	147337.708	92410.666	642.318	27	148382.105	91691.748	639.838
12	147337.712	92410.662	642.328	28	148382.116	91691.769	639.840
13	146844.599	92737.020	603.059	29	148898.966	91442.437	635.909
14	145846.448	92481.941	625.906	30	148739.889	91670.752	647.131
15	144277.108	91645.822	611.530	31	148972.252	92131.199	661.273
16	144984.678	91244.865	587.850	32	149553.698	92856.558	674.509

1- **Ad-dahiriya DTM (5 m cell size)**

Resampled Values of elevation and (ΔH) for each method of resampling are shown in table (5.12).

Table (5.12) Resampled Values of elevation and (ΔH) for each method

Point No.	Nearest Neighbor (m)	Δ(H1) (m)	Bi-Linear (m)	Δ(H2) (m)	Bi-Cubic (m)	Δ(H3) (m)
1	670.000	1.263	671.118	0.145	670.929	0.334
2	650.000	1.079	650.000	1.079	649.957	1.122
3	650.000	1.084	650.000	1.084	649.959	1.125
4	655.000	-0.149	655.000	-0.149	655.000	-0.149
5	655.000	-0.207	655.000	-0.207	655.000	-0.207
6	655.000	-0.685	655.000	-0.685	655.000	-0.685
7	635.000	3.135	637.538	0.597	637.570	0.565
8	640.000	-0.121	640.000	-0.121	639.983	-0.104

9	640.000	-0.338	640.000	-0.338	639.982	-0.320
10	640.000	0.198	640.000	0.198	640.010	0.188
11	644.688	-2.370	644.175	-1.857	644.351	-2.033
12	644.688	-2.360	644.179	-1.851	644.356	-2.028
13	605.000	-1.941	605.000	-1.941	605.000	-1.941
14	625.000	0.906	625.000	0.906	625.000	0.906
15	615.000	-3.470	615.000	-3.470	615.000	-3.470
16	590.000	-2.150	590.000	-2.150	590.000	-2.150
17	580.000	-0.337	580.000	-0.337	580.000	-0.337
18	620.000	-1.612	620.000	-1.612	619.991	-1.603
19	645.000	0.539	645.000	0.539	645.000	0.539
20	650.000	-1.815	649.871	-1.686	650.190	-2.005
21	605.000	0.756	605.000	0.756	605.000	0.756
22	590.000	-0.162	590.000	-0.162	590.000	-0.162
23	635.000	-0.848	635.000	-0.848	634.998	-0.846
24	635.336	4.522	637.549	2.309	637.609	2.249
25	635.000	2.127	635.000	2.127	634.869	2.258
26	620.000	2.943	620.000	2.943	620.000	2.943
27	640.000	-0.162	640.000	-0.162	640.000	-0.162
28	640.000	-0.160	640.000	-0.160	640.000	-0.160
29	635.000	0.909	635.000	0.909	635.000	0.909
30	645.000	2.131	645.000	2.131	645.008	2.123
31	660.000	1.273	660.000	1.273	660.000	1.273
32	675.000	-0.491	675.000	-0.491	675.000	-0.491

Table (5.13) shows the statistical results (Maximum and minimum values, Mean, RMSE) for this model.

Table (5.13) statistical results for Ad-dhahiriya DTM (5m cell size)

	∆(H1)	**∆(H2)**	**∆(H3)**
Minimum	-3.470	-3.470	-3.470
Maximum	4.522	2.943	2.943
Mean	0.109	-0.038	-0.049
RMSE	1.724	1.419	1.452

Table (5.14) shows the statistical results at 95% probability of observations for Ad-dhahiriya (5m cell size) DTM.

Table (5.14) Statistical results at 95% probability

	∆(H1)	**∆(H2)**	**∆(H3)**
Minimum	-2.370	-2.150	-2.150
Maximum	2.943	2.131	2.249
Mean	1.073	0.914	0.947
RMSE	0.825	0.701	0.735

2- Ad-dhahiriya DTM (10 m cell size)

Resampled elevation Values and (ΔH) for each method of resampling are shown in table(5.15)

Table (5.15) Resampled Values of elevation and (ΔH) for each method

Point No.	Nearest Neighbor (m)	Δ(H1) (m)	Bi-Linear (m)	Δ(H2) (m)	Bi-Cubic (m)	Δ(H3) (m)
1	675.000	-3.737	672.474	-1.211	672.575	-1.312
2	650.000	1.079	650.859	0.220	650.637	0.442
3	650.000	1.084	650.865	0.219	650.642	0.442
4	655.000	-0.149	655.000	-0.149	655.000	-0.149
5	655.000	-0.207	655.000	-0.207	655.000	-0.207
6	655.000	-0.685	655.000	-0.685	655.000	-0.685
7	640.000	-1.865	638.229	-0.094	638.387	-0.252
8	640.000	-0.121	640.000	-0.121	640.408	-0.529
9	640.000	-0.338	640.000	-0.338	640.447	-0.785
10	640.000	0.198	640.232	-0.034	639.958	0.240
11	644.688	-2.370	644.413	-2.095	644.521	-2.203
12	644.688	-2.360	644.415	-2.087	644.524	-2.196
13	605.000	-1.941	605.000	-1.941	605.000	-1.941
14	625.000	0.906	625.000	0.906	624.979	0.927
15	615.000	-3.470	615.000	-3.470	615.288	-3.758
16	590.000	-2.150	590.000	-2.150	590.000	-2.150
17	580.000	-0.337	580.000	-0.337	580.000	-0.337
18	620.000	-1.612	619.877	-1.489	619.960	-1.572
19	645.000	0.539	645.000	0.539	645.160	0.379
20	650.000	-1.815	647.891	0.294	647.921	0.264
21	605.000	0.756	605.000	0.756	604.864	0.892
22	590.000	-0.162	590.000	-0.162	590.000	-0.162
23	635.000	-0.848	635.000	-0.848	635.239	-1.087
24	639.342	0.516	637.938	1.920	638.078	1.780
25	635.000	2.127	634.868	2.259	634.541	2.586
26	620.000	2.943	620.004	2.939	619.999	2.944
27	640.000	-0.162	640.000	-0.162	640.000	-0.162
28	640.000	-0.160	640.000	-0.160	640.000	-0.160
29	635.000	0.909	635.000	0.909	635.000	0.909
30	645.000	2.131	645.104	2.027	644.935	2.196
31	660.000	1.273	660.000	1.273	660.000	1.273
32	675.000	-0.491	675.000	-0.491	675.000	-0.491

Table (5.16) shows the statistical results (Maximum and minimum values, Mean, RMSE) for this model

Table (5.16) statistical results for Ad-dhahiriya DTM (10 m cell size)

	∆(H1)	∆(H1)	∆(H1)
Minimum	-3.737	-3.470	-3.758
Maximum	2.943	2.939	2.944
Mean	1.226	0.990	1.085
RMSE	1.039	0.950	0.961

Table (5.17) shows the statistical results at 95% probability of observations for Ad-dhahiriya (10 m cell size) DTM.

Table (5.17) Statistical results at 95% probability

	∆(H1)	∆(H2)	∆(H3)
Minimum	-2.370	-2.150	-2.203
Maximum	2.131	2.027	2.196
Mean	1.010	0.822	0.901
RMSE	0.766	0.723	0.709

3- Ad-dhahiriya DTM (20 m cell size)

Resampled elevation Values and (∆H) for each method of resampling are shown in table(5.18)

Table (5.18) Resampled Values of elevation and (∆H) for each method

Point No.	Nearest Neighbor (m)	∆(H1) (m)	Bi-Linear (m)	∆(H2) (m)	Bi-Cubic (m)	∆(H3) (m)
1	675.000	-3.737	673.244	-1.981	673.333	-2.070
2	652.650	-1.571	651.660	-0.581	651.521	-0.442
3	652.650	-1.566	651.663	-0.579	651.525	-0.441
4	655.000	-0.149	655.000	-0.149	654.864	-0.013
5	655.000	-0.207	655.000	-0.207	654.865	-0.072
6	655.000	-0.685	655.000	-0.685	654.928	-0.613
7	640.000	-1.865	637.378	0.757	637.565	0.570
8	640.000	-0.121	639.511	0.368	639.612	0.267
9	640.000	-0.338	639.377	0.285	639.479	0.183
10	640.000	0.198	640.225	-0.027	640.183	0.015
11	640.000	2.318	642.413	-0.095	642.393	-0.075

12	640.000	2.328	642.414	-0.086	642.394	-0.066
13	605.000	-1.941	605.000	-1.941	605.000	-1.941
14	625.000	0.906	625.259	0.647	624.920	0.986
15	615.000	-3.470	615.000	-3.470	615.294	-3.764
16	590.000	-2.150	590.000	-2.150	590.010	-2.160
17	580.000	-0.337	580.000	-0.337	580.339	-0.676
18	620.000	-1.612	619.636	-1.248	620.025	-1.637
19	645.000	0.539	642.801	2.738	642.797	2.742
20	645.000	3.185	647.797	0.388	647.912	0.273
21	605.000	0.756	605.000	0.756	604.444	1.312
22	590.000	-0.162	590.000	-0.162	590.009	-0.171
23	635.000	-0.848	635.000	-0.848	635.686	-1.534
24	639.342	0.516	638.534	1.324	638.738	1.120
25	633.242	3.885	635.888	1.239	635.975	1.152
26	620.000	2.943	620.014	2.929	620.012	2.931
27	640.000	-0.162	640.000	-0.162	640.243	-0.405
28	640.000	-0.160	640.000	-0.160	640.242	-0.402
29	635.000	0.909	635.000	0.909	635.121	0.788
30	645.000	2.131	645.373	1.758	645.264	1.867
31	660.000	1.273	660.000	1.273	659.883	1.390
32	675.000	-0.491	675.000	-0.491	675.000	-0.491

Table (5.19) shows the statistical results (Maximum and minimum values, Mean, RMSE) for this model

Table (5.19) statistical results for Ad-dhahiriya DTM (20 m cell size)

	∆(H1)	∆(H2)	∆(H3)
Minimum	-3.737	-3.470	-3.764
Maximum	3.885	2.929	2.931
Mean	1.358	0.960	1.018
RMSE	1.144	0.895	0.944

Table (5.20) shows the statistical results at 95% probability of observations for Ad-dhahiriya (20 m cell size) DTM.

Table (5.20) Statistical results at 95% probability

	∆(H1)	∆(H2)	∆(H3)
Minimum	-2.150	-2.150	-2.160
Maximum	3.185	1.758	1.867
Mean	1.116	0.745	0.798
RMSE	0.903	0.614	0.668

4 -Ad-dhahiriya DTM (40 m cell size)

Resampled elevation Values and (ΔH) for each method of resampling are shown in table(5.21)

Table (5.21) Resampled Values of elevation and (ΔH) for each method

Point No.	Nearest Neighbor (m)	Δ(H1) (m)	Bi-Linear (m)	Δ(H2) (m)	Bi-Cubic (m)	Δ(H3) (m)
1	675.000	-3.737	674.076	-2.813	674.027	-2.764
2	652.650	-1.571	652.087	-1.008	652.249	-1.170
3	652.650	-1.566	652.089	-1.005	652.251	-1.167
4	655.000	-0.149	655.114	-0.263	654.848	0.003
5	655.000	-0.207	655.113	-0.320	654.848	-0.055
6	655.000	-0.685	655.062	-0.747	654.819	-0.504
7	635.000	3.135	635.997	2.138	635.744	2.391
8	640.000	-0.121	637.582	2.297	637.512	2.367
9	640.000	-0.338	637.503	2.159	637.414	2.248
10	640.000	0.198	639.387	0.811	639.205	0.993
11	640.000	2.318	641.241	1.077	640.990	1.328
12	640.000	2.328	641.242	1.086	640.991	1.337
13	605.000	-1.941	605.000	-1.941	605.102	-2.043
14	625.000	0.906	625.731	0.175	625.659	0.247
15	615.000	-3.470	613.228	-1.698	613.232	-1.702
16	590.000	-2.150	590.000	-2.150	590.140	-2.290
17	580.000	-0.337	579.625	0.038	579.480	0.183
18	615.000	3.388	618.302	0.086	618.035	0.353
19	640.000	5.539	642.231	3.308	642.196	3.343
20	650.000	-1.815	647.344	0.841	647.270	0.915
21	605.000	0.756	607.015	-1.259	606.493	-0.737
22	590.000	-0.162	590.000	-0.162	589.375	0.463
23	635.000	-0.848	632.979	1.173	632.966	1.186
24	640.000	-0.142	637.184	2.674	638.339	1.519
25	633.242	3.885	634.591	2.536	634.311	2.816
26	625.000	-2.057	622.363	0.580	622.488	0.455
27	640.000	-0.162	639.097	0.741	639.197	0.641
28	640.000	-0.160	639.100	0.740	639.200	0.640
29	635.000	0.909	634.898	1.011	635.365	0.544
30	645.000	2.131	646.598	0.533	647.023	0.108
31	660.000	1.273	660.000	1.273	659.936	1.337
32	675.000	-0.491	675.000	-0.491	675.071	-0.562

Table (5.22) shows the statistical results (Maximum and minimum values, Mean, RMSE) for this model

Table (5.22) statistical results for Ad-dhahiriya DTM (40 m cell size)

	Δ(H1)	Δ(H2)	Δ(H3)
Minimum	-3.737	-2.813	-2.764
Maximum	5.539	3.308	3.343
Mean	1.527	1.223	1.200
RMSE	1.373	0.874	0.898

Table (5.232) shows the statistical results at 95% probability of observations for Ad-dhahiriya (40 m cell size) DTM.

Table (5.23) Statistical results at 95% probability

	Δ(H1)	Δ(H2)	Δ(H3)
Minimum	-3.470	-2.150	-2.290
Maximum	3.388	2.536	2.391
Mean	1.232	1.046	1.017
RMSE	1.038	0.709	0.724

5.3.2.2 Halhul Contour Map

We got the contour map from Halhul Municipality with contour interval of (2.5 m), then we created DTM using ArcGIS with different cell size. The following table showing the GPS points used to evaluate the accuracy of these models.

Table(5.24) GNSS points which were used to evaluate - Halhul DTM accuracy

Point No.	Easting (m)	Northing (m)	Elevation (m)	Point No.	Easting (m)	Northing (m)	Elevation (m)
1	159547.199	108291.751	986.721	19	159448.436	110620.962	947.270
2	159790.002	108822.351	961.268	20	160058.900	111039.534	925.462
3	159790.005	108822.353	961.271	21	160222.976	111119.173	899.715
4	159581.511	109560.874	992.360	22	160535.362	110826.830	960.643
5	159929.087	109435.754	1002.180	23	160238.919	110346.187	966.968
6	160146.249	109060.582	970.832	24	160081.839	109789.046	1002.229
7	160241.803	108889.518	947.841	25	159141.557	109601.534	1001.679
8	160273.190	109474.573	1003.762	26	158768.495	109817.179	979.964
9	160976.827	109516.386	994.880	27	158870.281	110004.640	988.861
10	161206.378	110007.964	975.542	28	158520.615	110461.127	980.956
11	161206.375	110007.973	975.540	29	158515.773	110460.176	980.775
12	161025.656	111064.918	892.449	30	158156.919	111972.994	924.044
13	160434.815	111996.575	944.879	31	157525.777	110731.434	923.391
14	160101.058	111618.623	931.054	32	156488.569	111855.511	833.739
15	160101.065	111618.635	931.052	33	156660.596	110242.424	874.675
16	159751.418	111221.650	952.997	34	158748.215	108644.793	1011.948
17	158964.638	111113.594	931.747	35	158343.904	109157.744	951.636
18	159126.520	110598.827	962.169				

1 - halhul DTM (5 m cell size)

Resampled Values of elevation and (ΔH) for each method of resampling are shown in table (5.25).

Table (5.25) Resampled Values of elevation and (ΔH) for each method

Point No.	Nearest Neighbor (m)	Δ(H1) (m)	Bi-Linear (M)	Δ(H2) (m)	Bi-Cubic (m)	Δ(H3) (m)
1	985.000	1.721	985.000	1.721	984.985	1.736
2	961.409	-0.141	961.114	0.154	961.090	0.178
3	961.409	-0.138	961.114	0.157	961.091	0.180
4	992.719	-0.359	992.558	-0.198	992.343	0.017
5	1000.000	2.180	1000.000	2.180	999.999	2.181

6	970.000	0.832	969.740	1.092	969.768	1.064
7	946.572	1.269	946.574	1.267	946.563	1.278
8	1002.993	0.769	1002.888	0.874	1002.872	0.890
9	994.508	0.372	994.466	0.414	994.454	0.426
10	975.000	0.542	975.000	0.542	975.144	0.398
11	975.000	0.540	975.000	0.540	975.145	0.395
12	890.000	2.449	890.000	2.449	890.000	2.449
13	945.000	-0.121	944.986	-0.107	944.997	-0.118
14	930.000	1.054	930.703	0.351	930.420	0.634
15	930.000	1.052	930.709	0.343	930.425	0.627
16	950.000	2.997	950.298	2.699	950.209	2.788
17	930.000	1.747	930.000	1.747	929.946	1.801
18	960.000	2.169	960.000	2.169	959.969	2.200
19	945.000	2.270	945.000	2.270	945.010	2.260
20	925.000	0.462	925.042	0.420	924.914	0.548
21	898.919	0.796	898.534	1.181	898.422	1.293
22	960.000	0.643	960.000	0.643	960.000	0.643
23	967.268	-0.300	966.343	0.625	966.192	0.776
24	1002.977	-0.748	1002.142	0.087	1002.204	0.025
25	1000.000	1.679	1000.036	1.643	1000.052	1.627
26	981.099	-1.135	980.901	-0.937	980.985	-1.021
27	990.000	-1.139	990.000	-1.139	990.116	-1.255
28	979.865	1.091	979.827	1.129	979.808	1.148
29	979.893	0.882	979.786	0.989	979.782	0.993
30	926.698	-2.654	926.729	-2.685	926.784	-2.740
31	923.371	0.020	923.295	0.096	923.265	0.126
32	834.697	-0.958	834.888	-1.149	835.290	-1.551
33	875.000	-0.325	875.000	-0.325	875.016	-0.341
34	1004.091	7.857	1006.060	5.888	1006.012	5.936
35	950.000	1.636	950.066	1.570	949.990	1.646

Table (5.26) shows the statistical results (Maximum and minimum values, Mean, RMSE) for this model.

Table (5.26) statistical results for Halhul DTM (5m cell size)

	Δ(H1)	Δ(H2)	Δ(H3)
Minimum	-2.654	-2.685	-2.740
Maximum	7.857	5.888	5.936
Mean	1.287	1.194	1.237
RMSE	1.367	1.121	1.130

Table (5.27 shows the statistical results at 95% probability of observations for Halhul (5m cell size) DTM.

Table (5.27) Statistical results at 95% probability

	Δ(H1)	Δ(H2)	Δ(H3)
Minimum	-1.139	-1.149	-1.551
Maximum	2.270	2.270	2.260
Mean	0.938	0.905	0.948
RMSE	0.631	0.655	0.669

2 - halhul DTM (10 m cell size)

Resampled Values of elevation and (ΔH) for each method of resampling are shown in table (5.28).

Table (5.28) Resampled Values of elevation and (ΔH) for each method

Point No.	Nearest Neighbor (m)	Δ(H1) (m)	Bi-Linear (m)	Δ(H2) (m)	Bi-Cubic (m)	Δ(H3) (m)
1	985.000	1.721	986.493	0.228	986.142	0.579
2	960.443	0.825	960.843	0.425	960.831	0.437
3	960.443	0.828	960.843	0.428	960.831	0.440
4	989.622	2.738	993.030	-0.670	992.876	-0.516
5	1000.000	2.180	1000.000	2.180	999.575	2.605
6	969.079	1.753	969.689	1.143	969.973	0.859
7	946.573	1.268	946.573	1.268	946.562	1.279
8	1002.993	0.769	1002.885	0.877	1002.797	0.965
9	994.332	0.548	994.403	0.477	994.348	0.532
10	975.000	0.542	974.632	0.910	974.993	0.549
11	975.000	0.540	974.628	0.912	974.990	0.550
12	890.000	2.449	890.000	2.449	889.202	3.247
13	945.000	-0.121	944.973	-0.094	944.946	-0.067
14	930.000	1.054	931.216	-0.162	931.007	0.047
15	930.000	1.052	931.225	-0.173	931.015	0.037
16	953.256	-0.259	951.709	1.288	951.576	1.421
17	930.000	1.747	930.000	1.747	929.808	1.939
18	960.000	2.169	960.000	2.169	959.904	2.265
19	945.000	2.270	945.000	2.270	944.750	2.520
20	925.000	0.462	925.394	0.068	925.405	0.057
21	898.919	0.796	898.662	1.053	898.538	1.177
22	960.000	0.643	960.000	0.643	959.991	0.652
23	967.268	-0.300	966.935	0.033	966.798	0.170
24	1002.977	-0.748	1002.247	-0.018	1002.200	0.029
25	1000.000	1.679	1000.050	1.629	999.994	1.685
26	981.099	-1.135	980.655	-0.691	980.920	-0.956
27	990.000	-1.139	989.869	-1.008	990.152	-1.291
28	979.635	1.321	979.913	1.043	979.931	1.025

29	979.927	0.848	979.888	0.887	979.905	0.870
30	926.941	-2.897	926.310	-2.266	926.747	-2.703
31	922.129	1.262	923.570	-0.179	923.747	-0.356
32	834.697	-0.958	834.650	-0.911	834.782	-1.043
33	875.000	-0.325	874.784	-0.109	874.756	-0.081
34	1009.032	2.916	1006.554	5.394	1005.651	6.297
35	950.000	1.636	950.099	1.537	949.959	1.677

Table (5.29) shows the statistical results (Maximum and minimum values, Mean, RMSE) for this model.

Table (5.29) statistical results for Halhul DTM (10m cell size)

	Δ(H1)	Δ(H2)	Δ(H3)
Minimum	-2.897	-2.266	-2.703
Maximum	2.916	5.394	6.297
Mean	1.254	1.067	1.169
RMSE	0.772	1.028	1.219

Table (5.30shows the statistical results at 95% probability of observations for Halhul (10m cell size) DTM.

Table (5.30) Statistical results at 95% probability

	Δ(H1)	Δ(H2)	Δ(H3)
Minimum	-1.139	-1.008	-1.291
Maximum	2.270	2.180	2.520
Mean	1.105	0.851	0.896
RMSE	0.624	0.648	0.721

3- halhul DTM (20 m cell size)

Resampled Values of elevation and (ΔH) for each method of resampling are shown in table (5.31).

Table (5.31) Resampled Values of elevation and (ΔH) for each method

Point No.	Nearest Neighbor (m)	Δ(H1) (m)	Bi-Linear (m)	Δ(H2) (m)	Bi-Cubic (m)	Δ(H3) (m)
1	990.000	-3.279	988.660	-1.939	988.160	-1.439
2	961.436	-0.168	961.227	0.041	961.248	0.020
3	961.436	-0.165	961.226	0.045	961.248	0.023
4	996.542	-4.182	994.311	-1.951	994.496	-2.136
5	1000.000	2.180	1000.671	1.509	1000.507	1.673
6	969.079	1.753	969.584	1.248	969.380	1.452
7	946.550	1.291	946.731	1.110	946.185	1.656
8	1002.993	0.769	1003.314	0.448	1003.257	0.505
9	994.518	0.362	994.560	0.320	994.393	0.487
10	972.072	3.470	973.130	2.412	973.122	2.420
11	972.072	3.468	973.128	2.412	973.120	2.420
12	890.000	2.449	890.000	2.449	888.063	4.386
13	945.000	-0.121	944.972	-0.093	944.864	0.015
14	930.000	1.054	930.733	0.321	930.036	1.018
15	930.000	1.052	930.738	0.314	930.042	1.010
16	953.256	-0.259	952.656	0.341	952.524	0.473
17	930.000	1.747	929.570	2.177	929.441	2.306
18	960.000	2.169	960.142	2.027	959.632	2.537
19	945.000	2.270	945.649	1.621	945.576	1.694
20	925.532	-0.070	923.956	1.506	923.459	2.003
21	898.267	1.448	898.962	0.753	898.945	0.770
22	960.000	0.643	960.260	0.383	960.093	0.550
23	965.000	1.968	966.881	0.087	966.061	0.907
24	1000.000	2.229	1001.807	0.422	1001.624	0.605
25	999.457	2.222	1000.585	1.094	999.908	1.771
26	981.099	-1.135	980.344	-0.380	980.477	-0.513
27	990.000	-1.139	988.206	0.655	988.191	0.670
28	979.927	1.029	980.048	0.908	979.715	1.241
29	979.927	0.848	979.969	0.806	979.759	1.016
30	924.817	-0.773	925.427	-1.383	925.828	-1.784
31	925.000	-1.609	923.150	0.241	923.202	0.189
32	834.697	-0.958	834.878	-1.139	835.030	-1.291
33	870.000	4.675	873.997	0.678	873.887	0.788
34	1006.003	5.945	1008.950	2.998	1008.356	3.592
35	950.000	1.636	950.708	0.928	950.893	0.743

Table (5.32) shows the statistical results (Maximum and minimum values, Mean, RMSE) for this model.

Table (5.32) statistical results for Halhul DTM (20m cell size)

	Δ(H1)	Δ(H1)	Δ(H1)
Minimum	-4.182	-1.951	-2.136
Maximum	5.945	2.998	4.386
Mean	1.730	1.061	1.317
RMSE	1.349	0.810	0.977

Table (5.33shows the statistical results at 95% probability of observations for Halhul (20m cell size) DTM.

Table (5.33) Statistical results at 95% probability

	Δ(H1)	Δ(H2)	Δ(H3)
Minimum	-3.279	-1.951	-2.136
Maximum	3.468	2.177	2.420
Mean	1.429	0.915	1.112
RMSE	0.942	0.679	0.706

4- halhul DTM (40 m cell size)

Resampled Values of elevation and (ΔH) for each method of resampling are shown in table (5.34).

Table (5.34) Resampled Values of elevation and (ΔH) for each method

Point No.	Nearest Neighbor (m)	Δ(H1) (m)	Bi-Linear (m)	Δ(H2) (m)	Bi-Cubic (m)	Δ(H3) (m)
1	985.000	1.721	987.462	-0.741	987.176	-0.455
2	966.522	-5.254	965.230	-3.962	965.150	-3.882
3	966.522	-5.251	965.229	-3.958	965.149	-3.878
4	997.776	-5.416	994.902	-2.542	995.881	-3.521
5	1001.005	1.175	1001.089	1.091	1001.171	1.009
6	970.000	0.832	968.540	2.292	967.904	2.928
7	946.550	1.291	948.064	-0.223	947.883	-0.042
8	1005.729	-1.967	1004.925	-1.163	1005.142	-1.380
9	992.645	2.235	994.194	0.686	994.397	0.483
10	972.072	3.470	973.545	1.997	973.671	1.871
11	972.072	3.468	973.543	1.997	973.670	1.870
12	890.000	2.449	901.148	-8.699	901.338	-8.889
13	943.337	1.542	944.167	0.712	944.063	0.816
14	930.000	1.054	931.776	-0.722	931.665	-0.611
15	930.000	1.052	931.778	-0.726	931.668	-0.616
16	951.340	1.657	952.619	0.378	952.530	0.467
17	928.581	3.166	930.129	1.618	929.677	2.070

18	961.362	0.807	962.398	-0.229	961.824	0.345
19	945.000	2.270	944.899	2.371	944.878	2.392
20	930.290	-4.828	925.965	-0.503	925.654	-0.192
21	900.000	-0.285	899.205	0.510	898.554	1.161
22	960.000	0.643	960.523	0.120	960.622	0.021
23	969.993	-3.025	968.492	-1.524	967.847	-0.879
24	1000.545	1.684	1001.922	0.307	1002.315	-0.086
25	1000.000	1.679	1000.880	0.799	1001.224	0.455
26	981.099	-1.135	980.720	-0.756	980.812	-0.848
27	985.000	3.861	989.614	-0.753	990.129	-1.268
28	979.900	1.056	980.786	0.170	980.433	0.523
29	979.900	0.875	980.736	0.039	980.342	0.433
30	927.226	-3.182	924.481	-0.437	925.038	-0.994
31	925.000	-1.609	923.751	-0.360	923.788	-0.397
33	876.578	-1.903	874.970	-0.295	874.903	-0.228
34	1013.018	-1.070	1012.656	-0.708	1013.545	-1.597
35	954.380	-2.744	951.475	0.161	952.374	-0.738

Table (5.35) shows the statistical results (Maximum and minimum values, Mean, RMSE) for this model.

Table (5.35) statistical results for halhul DTM (40m cell size)

	Δ(H1)	Δ(H2)	Δ(H3)
Minimum	-5.416	-8.699	-8.889
Maximum	3.861	2.371	2.928
Mean	2.225	1.281	1.392
RMSE	1.400	1.629	1.678

Table (5.36shows the statistical results at 95% probability of observations for halhul (40m cell size) DTM.

Table (5.36) Statistical results at 95% probability

	Δ(H1)	Δ(H2)	Δ(H3)
Minimum	-3.182	-1.524	-1.597
Maximum	3.861	2.371	2.928
Mean	1.927	0.869	0.990
RMSE	1.068	0.709	0.845

5.3.2.3Hebron Contour Map.

We got the contour map from Hebron Municipality with contour interval of (2.5 m), then we created DTM using ArcGIS with different cell size. The following table showing the GPS points used to evaluate the accuracy of these models.

Table(5.37) GNSS points which were used to evaluate Hebron DTM accuracy

Point No.	Easting (m)	Northing (m)	Elevation (m)	Point No.	Easting (m)	Northing (m)	Elevation (m)
1	160484.908	102025.123	859.659	18	158403.500	101514.990	893.967
2	158796.346	101759.632	891.571	19	158361.606	101517.234	889.254
3	158536.802	102567.532	937.613	20	157559.869	101702.707	877.782
4	160246.713	103037.819	917.844	21	157606.323	101653.856	871.791
5	161370.517	103249.118	951.681	22	157471.896	100997.087	856.241
6	160081.128	103989.869	908.583	23	157616.344	102647.505	884.991
7	159079.737	103885.410	919.452	24	158205.721	103638.033	954.112
8	160992.809	106156.615	956.782	25	158415.713	103257.299	959.002
9	159177.604	101236.847	883.576	26	158594.420	105698.326	913.598
10	161231.729	101017.458	808.997	27	159009.348	106272.690	949.395
11	159797.016	105523.742	971.759	28	159160.570	106932.973	992.820
12	160210.141	105976.939	984.476	29	157960.956	107235.333	996.109
13	160210.119	105976.946	984.490	30	158214.694	105809.139	954.932
14	160085.864	107126.108	987.364	31	157840.384	105284.859	954.128
15	160732.314	106983.339	1006.037	32	157646.401	104235.468	968.349
16	160137.720	107608.185	1002.034	33	157268.915	103287.719	931.650
17	159607.596	107823.066	962.770				

1- Hebron DTM (5 m cell size)

Resampled Values of elevation and (ΔH) for each method of resampling are shown in table (5.38).

Table (5.38) Resampled Values of elevation and (ΔH) for each method

Point No.	Nearest Neighbor (m)	Δ(H1) (m)	Bi-Linear (m)	Δ(H2) (m)	Bi-Cubic (m)	Δ(H3) (m)
1	858.813	0.846	858.782	0.877	858.780	0.879
2	891.742	-0.171	891.715	-0.144	891.708	-0.137
3	936.816	0.797	936.553	1.060	936.578	1.035
4	916.847	0.997	916.923	0.921	916.826	1.018
5	952.274	-0.593	952.235	-0.554	952.269	-0.588
6	909.971	-1.388	910.025	-1.442	910.088	-1.505
7	917.224	2.228	917.239	2.213	917.235	2.217
8	957.668	-0.886	957.709	-0.927	957.722	-0.940

9	882.437	1.139	881.797	1.779	881.810	1.766
10	810.000	-1.003	810.000	-1.003	810.000	-1.003
11	972.689	-0.930	972.663	-0.904	972.721	-0.962
12	984.736	-0.260	984.806	-0.330	984.836	-0.360
13	984.736	-0.246	984.805	-0.315	984.835	-0.345
14	987.500	-0.136	987.500	-0.136	987.501	-0.137
15	1006.181	-0.144	1006.454	-0.417	1006.480	-0.443
16	1001.556	0.478	1001.970	0.064	1002.005	0.029
17	962.223	0.547	962.334	0.436	962.327	0.443
18	893.169	0.798	892.982	0.985	892.947	1.020
19	887.504	1.750	887.713	1.541	887.686	1.568
20	874.832	2.950	874.992	2.790	874.901	2.881
21	870.565	1.226	870.759	1.032	870.754	1.037
22	855.417	0.824	856.059	0.182	856.048	0.193
23	884.957	0.034	884.939	0.052	884.957	0.034
24	951.834	2.278	951.911	2.201	951.948	2.164
25	958.307	0.695	957.933	1.069	957.920	1.082
26	912.929	0.669	912.856	0.742	912.835	0.763
27	950.003	-0.608	950.023	-0.628	950.031	-0.636
28	994.145	-1.325	993.855	-1.035	993.859	-1.039
29	995.407	0.702	995.555	0.554	995.525	0.584
30	954.990	-0.058	954.998	-0.066	955.030	-0.098
31	952.500	1.628	952.500	1.628	952.500	1.628
32	966.520	1.829	966.832	1.517	966.842	1.507
33	931.437	0.213	931.079	0.571	931.086	0.564

Table (5.39) shows the statistical results (Maximum and minimum values, Mean, RMSE) for this model.

Table (5.39) statistical results for Hebron DTM (5m cell size)

	∆(H1)	**∆(H2)**	**∆(H3)**
Minimum	-1.388	-1.442	-1.505
Maximum	2.950	2.790	2.881
Mean	0.921	0.912	0.927
RMSE	0.689	0.677	0.676

Table (5.40) shows the statistical results at 95% probability of observations for Hebron (5m cell size) DTM.

Table (5.40) Statistical results at 95% probability

	∆(H1)	∆(H2)	∆(H3)
Maximum	1.829	1.779	1.766
Minimum	-1.388	-1.442	-1.505
Mean	0.764	0.764	0.778
RMSE	0.492	0.493	0.496

2- Hebron DTM (10 m cell size)

Resampled Values of elevation and (ΔH) for each method of resampling are shown in table (5.41).

Table (5.41) Resampled Values of elevation and (ΔH) for each method

Point No.	Nearest Neighbor (m)	∆(H1) (m)	Bi-Linear (m)	∆(H2) (m)	Bi-Cubic	∆(H)3
1	857.720	1.939	858.743	0.916	858.731	0.928
2	891.813	-0.242	891.754	-0.183	891.744	-0.173
3	937.103	0.510	936.542	1.071	936.587	1.026
4	916.068	1.776	917.421	0.423	917.519	0.325
5	952.274	-0.593	952.226	-0.545	952.269	-0.588
6	909.971	-1.388	909.979	-1.396	910.018	-1.435
7	917.309	2.143	917.373	2.079	917.392	2.060
8	957.807	-1.025	957.666	-0.884	957.575	-0.793
9	880.877	2.699	881.511	2.065	881.465	2.111
10	810.000	-1.003	810.000	-1.003	810.000	-1.003
11	972.661	-0.902	972.395	-0.636	972.412	-0.653
12	984.904	-0.428	984.702	-0.226	984.738	-0.262
13	984.904	-0.414	984.702	-0.212	984.737	-0.247
14	987.500	-0.136	987.493	-0.129	987.527	-0.163
15	1005.957	0.080	1006.337	-0.300	1006.415	-0.378
16	1001.556	0.478	1001.961	0.073	1002.011	0.023
17	962.500	0.270	962.457	0.313	962.645	0.125
18	892.521	1.446	893.101	0.866	893.126	0.841
19	887.501	1.753	887.745	1.509	887.745	1.509
20	875.117	2.665	875.022	2.760	874.892	2.890
21	871.256	0.535	870.822	0.969	870.834	0.957
22	855.959	0.282	856.033	0.208	855.977	0.264
23	884.906	0.085	884.737	0.254	884.644	0.347

24	952.487	1.625	951.708	2.404	951.808	2.304
25	957.641	1.361	957.856	1.146	957.833	1.169
26	913.468	0.130	912.997	0.601	912.904	0.694
27	949.872	-0.477	950.087	-0.692	950.125	-0.730
28	993.343	-0.523	993.795	-0.975	993.803	-0.983
29	995.003	1.106	995.811	0.298	995.878	0.231
30	953.749	1.183	954.637	0.295	954.665	0.267
31	952.500	1.628	952.500	1.628	952.501	1.627
32	967.652	0.697	966.784	1.565	966.706	1.643
33	931.437	0.213	931.111	0.539	931.105	0.545

Table (5.42) shows the statistical results (Maximum and minimum values, Mean, RMSE) for this model.

Table (5.42) statistical results for Hebron DTM (10m cell size)

	∆(H1)	∆(H2)	∆(H3)
Minimum	-1.388	-1.396	-1.435
Maximum	2.699	2.760	2.890
Mean	0.962	0.884	0.888
RMSE	0.736	0.694	0.705

Table (5.43) shows the statistical results at 95% probability of observations for Hebron (5m cell size) DTM.

Table (5.43) Statistical results at 95% probability

	∆(H1)	∆(H2)	∆(H3)
Minimum	-1.388	-1.396	-1.435
Maximum	1.939	2.065	2.111
Mean	0.808	0.731	0.733
RMSE	0.573	0.514	0.522

3- Hebron DTM (20 m cell size)

Resampled Values of elevation and (∆H) for each method of resampling are shown in table (5.44).

Table (5.44) Resampled Values of elevation and (∆H) for each method

Point No.	Nearest Neighbor (m)	∆(H1) (m)	Bi-Linear (m)	∆(H2) (m)	Bi-Cubic (m)	∆(H3) (m)
1	859.052	0.607	858.810	0.849	858.913	0.746
2	891.813	-0.242	891.753	-0.182	891.749	-0.178
3	935.548	2.065	936.180	1.433	936.159	1.454

4	919.622	-1.778	917.600	0.244	917.607	0.237
5	952.413	-0.732	951.634	0.047	951.839	-0.158
6	906.136	2.447	909.782	-1.199	909.791	-1.208
7	917.397	2.055	917.436	2.016	917.472	1.980
8	957.661	-0.879	957.466	-0.684	957.364	-0.582
9	880.877	2.699	881.598	1.978	881.573	2.003
10	810.000	-1.003	810.000	-1.003	810.000	-1.003
11	972.661	-0.902	972.275	-0.516	972.272	-0.513
12	985.377	-0.901	984.367	0.109	984.436	0.040
13	985.377	-0.887	984.366	0.124	984.435	0.055
14	987.454	-0.090	987.595	-0.231	987.705	-0.341
15	1007.121	-1.084	1006.330	-0.293	1006.413	-0.376
16	1003.521	-1.487	1001.990	0.044	1002.241	-0.207
17	962.500	0.270	962.346	0.424	962.531	0.239
18	892.585	1.382	892.982	0.985	892.991	0.976
19	887.501	1.753	887.706	1.548	887.719	1.535
20	875.117	2.665	875.114	2.668	875.120	2.662
21	870.288	1.503	870.763	1.028	870.757	1.034
22	857.529	-1.288	856.089	0.152	856.064	0.177
23	885.682	-0.691	885.073	-0.082	884.917	0.074
24	950.684	3.428	951.157	2.955	951.194	2.918
25	957.641	1.361	957.816	1.186	957.799	1.203
26	912.500	1.098	913.148	0.450	913.084	0.514
27	952.444	-3.049	949.996	-0.601	949.926	-0.531
28	994.764	-1.944	993.947	-1.127	993.965	-1.145
29	995.003	1.106	995.674	0.435	995.734	0.375
30	957.283	-2.351	954.452	0.480	954.804	0.128
31	952.500	1.628	952.497	1.631	952.507	1.621
32	965.846	2.503	966.823	1.526	966.764	1.585
33	929.901	1.749	930.973	0.677	931.038	0.612

Table (5.45) shows the statistical results (Maximum and minimum values, Mean, RMSE) for this model.

Table(5.45) statistical results for Hebron DTM (20m cell size)

	∆(H1)	**∆(H2)**	**∆(H3)**
Minimum	-3.049	-1.199	-1.208
Maximum	3.428	2.955	2.918
Mean	0.861	0.876	1.348
RMSE	0.752	0.748	0.677

Table (5.46) shows the statistical results at 95% probability of observations for Hebron (20m cell size) DTM.

Table (5.46) Statistical results at 95% probability

	∆(H1)	∆(H2)	∆(H3)
Minimum	-2.351	-1.199	-1.208
Maximum	2.699	1.978	1.980
Mean	1.348	0.709	0.694
RMSE	0.677	0.541	0.550

4- Hebron DTM (40 m cell size)

Resampled Values of elevation and (ΔH) for each method of resampling are shown in table (5.47).

Table (5.47) Resampled Values of elevation and (ΔH) for each method

Point No.	Nearest Neighbor (m)	∆(H1) (m)	Bi-Linear (m)	∆(H2)	Bi-Cubic (m)	∆(H3)
1	860.772	-1.113	858.689	0.970	859.155	0.504
2	889.858	1.713	891.514	0.057	891.374	0.197
3	937.430	0.183	936.212	1.401	936.294	1.319
4	914.977	2.867	916.192	1.652	916.365	1.479
5	952.601	-0.920	951.059	0.622	951.691	-0.010
6	907.975	0.608	909.083	-0.500	909.043	-0.460
7	920.025	-0.573	917.506	1.946	917.450	2.002
8	955.655	1.127	958.082	-1.300	957.755	-0.973
9	885.929	-2.353	881.891	1.685	881.993	1.583
10	810.000	-1.003	810.000	-1.003	809.939	-0.942
11	970.681	1.078	972.370	-0.611	972.321	-0.562
12	985.377	-0.901	984.147	0.329	984.332	0.144
13	985.377	-0.887	984.145	0.345	984.331	0.159
14	988.594	-1.230	986.947	0.417	986.924	0.440
15	1007.121	-1.084	1006.575	-0.538	1006.859	-0.822
16	999.835	2.199	1001.314	0.720	1001.678	0.356
17	962.500	0.270	961.546	1.224	961.643	1.127
18	894.924	-0.957	892.897	1.070	893.287	0.680
19	890.042	-0.788	887.503	1.751	887.900	1.354
20	877.414	0.368	875.202	2.580	875.418	2.364
21	870.033	1.758	870.619	1.172	870.209	1.582
22	852.805	3.436	856.345	-0.104	856.255	-0.014
23	885.028	-0.037	885.067	-0.076	884.531	0.460
24	952.496	1.616	950.698	3.414	951.136	2.976
25	957.641	1.361	957.754	1.248	957.867	1.135
26	914.871	-1.273	913.960	-0.362	913.830	-0.232
27	947.534	1.861	949.992	-0.597	949.967	-0.572
28	994.888	-2.068	993.150	-0.330	993.459	-0.639
29	999.166	-3.057	995.190	0.919	995.525	0.584

30	953.260	1.672	953.436	1.496	953.785	1.147
31	952.367	1.761	952.389	1.739	953.225	0.903
32	968.310	0.039	966.837	1.512	966.746	1.603
33	930.569	1.081	930.911	0.739	931.036	0.614

Table (5.47) shows the statistical results (Maximum and minimum values, Mean, RMSE) for this model.

Table(5.48) statistical results for Hebron DTM (40m cell size)

	∆(H1)	∆(H2)	∆(H3)
Minimum	-3.057	-1.300	-0.973
Maximim	3.436	3.414	2.976
Mean	1.310	0.715	0.590
RMSE	1.533	0.734	0.679

Table (5.49) shows the statistical results at 95% probability of observations for Hebron (40m cell size) DTM.

Table (5.49) Statistical results at 95% probability

	∆(H1)	∆(H2)	∆(H3)
Minimum	-2.353	-1.300	-0.973
Maximum	2.199	1.751	1.603
Mean	1.129	0.883	0.753
RMSE	0.614	0.523	0.479

Chapter 6 conclusion and recommendations

6.1 conclusions

6.2 Recommendations

6.1 conclusions

Using our study and the analysis of the data, we concluded the following

1. Much of the local and global model are not documented and unknown date of producing or resource.
2. The global and local models were successfully tested and evaluated.
3. The models were evaluated by applying the most common resampling methods. The methods are Nearest Neighbor, Bi-Linear and Bi-Cubic.
4. The results of these tests are summarized in table (6.1), for STRM3,SRTM30 and GTOPO30. The tests were applied depend on the USGS 1998 standard and procedure (at 95% confidence level).

(6.1) Summarized for STRM3, STRM30, GTPOP The tests were applied depend on the USGS 1998 standard and procedure (at 95% confidence level).

Modle	STRM 3			STRM 30			GTOPO 30		
Resampling Methods / Results	Nearest Neighbor	Bi-Linear	Bi-Cubic	Nearest Neighbor	Bi-Linear	Bi-Cubic	Nearest Neighbor	Bi-Linear	Bi-Cubic
MAX	**15.510**	**17.106**	**14.330**	**82.980**	**73.552**	**69.890**	**101.604**	**83.569**	**86.59**
MIN	**-10.100**	**-9.122**	**-9.476**	**-69.170**	**-70.78**	**-70.53**	**-83.1**	**-70.59**	**-80.57**
Mean	**5.177**	**6.078**	**4.77**	**32.210**	**34.355**	**33.817**	**33.809**	**31.074**	**32.24**
RMSE	**3.356**	**3.558**	**3.077**	**19.734**	**17.886**	**17.692**	**31.256**	**23.607**	**23.86**

5. Best result for measuring the heights using global models were obtained from SRTM3 and by applying Bi-Cubic resampling method.
6. The local models were converted from lines to DEM by using ArcGIS with gradually changing of cell size (5, 10 20 40)m cell size for each model.
7. The models were evaluated by applying the most common resampling methods. The methods are Nearest Neighbor, Bi-Linear and Bi-Cubic.
8. The results of these tests are summarized in tables (6.2), (6.3) and (6.4)
9. for Ad-dhahriya, Hebron and Halhul contour maps. The tests were applied depend on the USGS 1998 standard and procedure (at 95% confidence level).

(6.2) summarized Ad-dhahiriya Model with gradually changing of cell size (5, 10 20 40)m cell size for each model

Cell Size(m)	5			10			20			40		
Resampling Method / Results	Nearest Neghbor	Bi-Linear	Bi-Cubic	Nearest Neighbor	Bi-Linear	Bi-Cubic	Nearest Neighbor	Bi-Linear	Bi-Cubic	Nearest Neighbor	Bi-Linear	Bi-Cubic
MAX	-2.37	-2.15	-2.15	-2.37	-2.15	-2.20	-2.15	-2.15	-2.16	-3.47	-2.15	-2.29
MIN	2.943	2.13	2.24	2.131	2.027	2.196	3.185	1.758	1.867	3.388	2.536	2.391
MEAN	1.073	0.914	0.947	1.010	0.822	0.901	1.116	0.745	0.798	1.232	1.046	1.017
RMSR	0.825	0.701	0.735	0.766	0.723	0.709	0.903	0.614	0.668	1.038	0.709	0.724

(6.3) summarized- Halhul Model with gradually changing of cell size (5, 10 20 40)m cell size for each model

Cell Size(m)	5			10			20			40		
Resampling Method / Results	Nearest Neighbor	Bi-Linear	Bi-Cubic	Nearest Neighbor	Bi-Linear	Bi-Cubic	Nearest Neighbor	Bi-Linear	Bi-Cubic	Nearest Neighbor	Bi-Linear	Bi-Cubic
MAX	-1.13	-1.14	-1.55	-1.13	-1.00	-1.29	-3.27	-1.95	-2.13	-3.18	-1.52	-1.59
MIN	2.270	2.270	2.260	2.270	2.180	2.520	3.468	2.177	2.420	3.861	2.371	2.928
MEAN	0.938	0.905	0.948	1.105	0.851	0.896	1.429	0.915	1.112	1.927	0.869	0.990
RMSR	0.631	0.655	0.669	0.624	0.648	0.721	0.942	0.679	0.706	1.068	0.709	0.845

(6.4) summarized Hebron Model with gradually changing of cell size (5, 10 20 40)m cell size for each model

Cell Size(m)	5			10			20			40		
Resampling Method / Results	Nearest Neighbor	Bi-Linear	Bi-Cubic	Nearest Neighbor	Bi-Linear	Bi-Cubic	Nearest Neighbor	Bi-Linear	Bi-Cubic	Nearest Neighbor	Bi-Linear	Bi-Cubic
MAX	1.829	1.77	1.76	-1.38	-1.39	-1.43	-2.35	-1.19	-1.20	-2.35	-1.30	-0.97
MIN	-1.38	-1.44	-1.50	1.939	2.065	2.111	2.699	1.978	1.980	2.199	1.751	1.603
MEAN	0.764	0.764	0.778	0.808	0.731	0.733	1.348	0.709	0.694	1.129	0.883	0.753
RMSR	0.492	0.493	0.496	0.573	0.514	0.522	0.677	0.541	0.550	0.614	0.523	0.479

10. Best result for measuring the heights using Ad-dhahriya model were obtained from (20 cell size model) and by applying Bi linear resampling method. And from halhul model were obtained from (10 cell size model) and applying Nearest neighbor .And from hebron model were obtained from(40 cell size model) and by applying Bi Cubic

6.2 Recommendations

Depending on our results we recommend the following:

1- Make sure from the accuracy of contour maps and DEMs before using it.
2- Choose the best resampling method for measuring the heights from DEMs.
3- Depending on results, necessity to choose the best DEM according to the application that it will be used for.
4- Necessity of finding methodology to adjust the quality of producing contour maps from aerial photos.
5- Necessity of documenting maps accuracy and resource and production date and knowing it before use.

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